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PSYCHOLOGICAL FACTORS IN VOCATIONAL GUIDANCE¹

THOMAS A. LEWIS

Vocational guidance is a short name for "the conservation of the energies and talents of human workers." The object is to secure for the new generation, by expert assistance, that occupational adjustment which reduces waste and worry to a minimum. It is an attempt to afford boys and girls and young people the aid so much needed by them in order that they may choose the vocations in which they will have the best chance for personal success and for public usefulness. Putting the matter concretely, it is an attempt to prevent such situations as that typified by the firm which utilizes the services of a thousand salesmen, but "to keep the ranks of that thousand full hires from five to seven thousand men a year."

The main field for vocational guidance is in schools and colleges, because by centering the undertaking there practically every person who has yet to choose a vocation may be reached and that at an opportune time. With guidance machinery installed in the later elementary grades the 40 per cent that drops out as soon as the law allows will not fail to receive its benefits, and with this machinery still operating in the college those who make their decisions at this relatively late age will not be neglected. Vocational guidance in connection with manual vocations extends out into the occupation in the case of those pupils who enter the busy world early and need "follow-up" supervision to keep them from getting trapped in "blind-alley" jobs; and in the case of students in educational institutions where the "part-time" plan is in operation, and where the student divides his time between school and work. In this latter

¹ Address of the retiring President at the regular semi-monthly meeting of the Denison Scientific Association, October 7, 1919.

instance guidance takes its cue as much from the way the individual gets along "on the job" as from the run of things in his study-life. There is an extreme swing of vocational guidance to the occupational end in the case where the psychological expert stands at the door of the business concern and by use of various kinds of tests attempts to find the right men for the different places, shutting out the others.

There is more to vocational guidance, of course, than just what is being done by the psychologist in his diagnostic testing. In the opinion of the Commission on the Reorganization of Secondary Education, "vocational guidance should be a continuous process designed to help the individual to choose, to plan his preparation for, to enter upon, and to make progress in an occupation." That this task is many-sided and therefore calls for the coöperation of many minds is indicated by the nature of the program set by the committee for carrying it through. The program consists of eight steps, as follows:

1. Survey of the world's work.
2. Studying and testing pupils' possibilities.
3. Guidance in choice and rechoice of vocation.
4. Guidance with reference to preparation for vocation.
5. Guidance in entering upon work; that is, "placement."
6. Guidance in employment; that is, "employment supervision."
7. Progressive modification of school practices.
8. Progressive modification of economic conditions.

The outline, it will be seen, assigns sufficient work for teacher, school administrator, vocational counsellor, parent, psychologist, and others. It is only to be noted that the psychologist is assigned a particular part, namely, "studying and testing pupils' possibilities." Not that he alone is assigned this topic, though there is evidence that his services here are going to increase in volume and reliability.

The late Prof. Hugo Muensterberg, of Harvard University, was very optimistic about the future of vocational psychology. He thought that the problem of vocational guidance "had

already been handed over from the vocational counsellors to the experimental psychologists." In his mind, "the laboratory method" was as superior to the "mere-impression" method as "the microscope is superior to the human eye." As a rule the investigators in this line are more moderate in their claims and expectations, and for the two reasons, namely that (1) the technique of mental measurement is not so highly perfected as the microscope and (2) the material to be dealt with is of the most complex kind.

The committee on vocational guidance appointed by the National Education Association makes a three-fold classification of the experimental work being carried on by the vocational psychologist, namely:

(1) The attempt to supply the employer with tests that will enable him to select from a large number of applicants those most likely to succeed in a given position (vocational selection); (2) the attempt to determine specific vocational abilities—that is, which of several occupations would be the best one for a given individual to follow; (3) the attempt to develop tests for the measurement of general intelligence.

Professor Muensterberg, who was one of the first men in this country to go at the matter of vocational guidance laboratory fashion, performed experiments to weed out applicants and also to discover personal aptitude. His tests (which were not of the general intelligence variety, but were tests of reaction time, association, attention, etc.) were applied, as he said, from the side of "the scientific manager who seeks the best man for the work; and from the side of the vocational counsellor who seeks the best work for the man." He thought that by so doing the interests of both sides were provided for. Being a pioneer in this new world of discovery, Muensterberg did not blaze the way very far, but what he did was of practical value and rather significant. His investigations were concerned with finding out what sort of equipment was required of a person who could be counted on to succeed as a typesetter, a motorman, a telephone operator, etc. His methods and results in the case of the motorman are typical. Assuming that for motormen on street rail-

ways "the essential ability consists in the power to combine continuous attention with an impulse to quick reaction, and with a certain imagination by which the movements of pedestrians and vehicles are foreseen," he contrived a device whereby it was possible to test a man for these specific characteristics. There was a crank which the subject turned, and red and black puppet figures that appeared on a passing screen in different combinations, and the noting of certain particular combinations seemed to be the thing that told the tale. The number of the mistakes made in this particular and the rapidity in turning the crank were measured. "Experienced motormen felt, in carrying out this experiment," says Muensterberg, "that the mental attitude was indeed quite similar to that of their function on the street." He remarks upon the fact that "13 per cent of the gross receipts of some roads go for damages due to avoidable accidents," and significantly adds that his "experiments resulted in the rejection of one-fourth of the applicants for positions as motormen."

Other men engaged in psychological research have also become greatly interested in recent years in the practical possibilities of the science, and in some institutions of higher education (Carnegie Institute of Technology, for example) applied psychology has assumed large proportions.

But it is the service performed in connection with the organization of our recent Army that vocational psychology stands out. Psychology here undertook a task of mental engineering which was on a scale so vast as to require of the specialists in that field the abandonment for the duration of the war of many or all of their other duties. The classification of the membership of the Army on the basis of trade abilities and general intelligence and officer qualities was largely the psychologist's responsibility. The dual problem (set by Muensterberg) of studying the man and the occupation as the prime fundamental in vocational guidance, was attacked in great earnestness, and with the result that it became possible to select officers with some assurance that right selections were being made, to classify recruits according to their capacities both to learn what a soldier must

know and to do what a soldier must do, and "to locate every man that had any kind of special skill that the Army might need." The methods followed in working up these different tests, as well as the results obtained by their use, are significant as indicating the way the thing must be done if any contribution to vocational guidance is to be made from this source. In formulating the trade tests, to use this set of tests as an example,

The committee sought material from all promising sources. These included skilled mechanics in all the trades represented, trade-union officials, employment managers, factory superintendents and foremen, the United States Bureau of Labor Statistics, civil service examiners, and Army officers in all branches of the service.

A first-hand study was made of the mechanic on his job. With the assistance of skilled workers in each trade, the essential elements of the processes involved were selected and classified. These were then translated into questions which might be used to test the capacity of the worker.

In addition to the oral test, here described, there were picture and performance tests. "The picture test required the candidate to identify certain technical processes and details relating to the trade," and the performance test "required the candidate to carry through some operation, or construct some piece of work, which involved the essential processes of the trade."

Raymond Dodge points out the fact that

These tests standardized for the first time in America the classification of novices, apprentices, journeymen, and experts in the most important trades. The scientific care with which these trade tests were prepared may be indicated by the fact that each test before it was adopted passed through a process of development, trial, and evaluation consisting of twelve distinct stages.

A question in one of these finished-up tests for telephone repair men is given by Randall in the *American Magazine* for April, 1919:

Some of the questions (the trade test questions) are very interesting. For example here is one that will set off a journeyman telephone repair

man from an apprentice: "Why is it that when a subscriber tips the telephone instrument in talking, the party at the other end does not hear so well?"

The answer is that the sound box in the instrument contains a lot of little carbon granules which, when put under pressure by the sound waves of the voice, transmit electricity. The harder the pressure the more electricity they transmit, and the better the voice is carried. Tip the instrument, and the granules, which are loosely packed, are displaced, and the person at the other end says, "I don't hear, you'll have to speak a little louder."

A journeyman repair man knows that, because he is expected to open sound boxes and fix them when they are wrong. An apprentice is forbidden, under any circumstances, to open a sound box. His functions are limited to taking a faulty sound box out and putting a perfect one in; and he never sees the inside of one of them.

To the oral tests were added picture tests. One of these—the test for typewriter repair men—I myself took. A four-page leaflet was put in my hands, containing on each page a picture of one section of a typewriter. There were twenty questions on this order: "What is the purpose of the screw marked B?" "If your carriage was running too slow what part of the machine would you adjust?" The test proved that as a typewriter repair man I rank as a low apprentice—which is about right.

In the same concrete fashion, Randall gives an example of a performance test—one for an automobile repair man. In this case the man was a "frame-up"—a person coached for the occasion just to see if he could not weather the automobile test, though in fact only a novice. Randall says:

He appeared in camp, and on the oral tests made a perfect record, which was so unusual as to excite the admiration of the examiner. The result was that he was led into a tent where a certain part of an automobile lay on the table in pieces, and left to put it together. The examiner discovered him a half-hour later. The part was screwed together and looked pretty workmanlike. But the candidate had forgotten entirely to put in any packing, and he was cudgeling his brain to discover what the two springs and a bolt for which he had found no place could possibly be intended for.

If both the tests for general intelligence and the trade tests could be incorporated in a vocational guidance program for the school and the college it would be possible to estimate the individual's all-round capacity as well as any special capacity that he might have. The trade tests to be used with novices or vocationally untrained persons, as would be the case here, would have to be framed to sound native bent, and not to sound (as was the case in the Army) the capacity the person had by virtue of specific vocational training. Not much has so far been done along this line and it may be too much to expect that a great deal can be done. Professor Seashore of the University of Iowa seems to have succeeded in testing for musical ability, and there are a number of men who are busy trying to contrive tests that will have forecasting value in other directions. Dean Schneider of the College of Engineering, University of Cincinnati, is sceptical and maintains that the only way to test for vocational fitness or unfitness is "on the job." It may be, however, that the remarkable success of the trade tests in the Army—confuting the sceptic—will have both a heartening and enlightening effect, and that in consequence real things will be achieved before many years in creating and applying similar tests in educational institutions.

With respect to the general intelligence tests, it seems fair to say that as a rule they do really test, though in a more or less rough way. As adapted for military use (under the name Army recruit test) they counted for something. Thorndike, one of the men who figured prominently in this adaptation, and the man into whose hands was given the preparation of the tests for entrance to Columbia University, while acknowledging the large possibility for error in the results obtained through the use of tests for general intelligence, still holds that "the test score may always be of great value, since it is a clear addition to the available impressionistic knowledge; it taps a new source of information."

A few of the tests in which most faith is placed may be added here. They are of such rank as to have been closely patterned after in the Army. Reference to the army tests can only be

indirect as their publication is forbidden under penalty. These examples are taken from Terman's *The Measurement of Intelligence*.

First, the "dissected-sentence" test. The sentences are to be put in right order.

- (a) For the started an we country early at hour.
- (b) To asked paper my teacher correct I my.
- (c) A defends dog good his bravely master. . . . false true

In the corresponding army test, which contained false as well as true statements, the men had not only to rearrange the disarranged words but had also to indicate whether true or false, by underlining as in sentence (c) above.

A second test is that of "detecting absurdities," used by the army also, only with modified content and with somewhat different instructions. In the Army, those taking the test were told to write the letter "f" before each of the statements which could not possibly be true.

- (a) A man said: "I know a road from my house to the city which is downhill all the way to the city and downhill all the way back home."
- (b) An engineer said that the more cars he had on his train the faster he could go.
- (c) Yesterday the police found the body of a girl cut in eighteen pieces. They believe that she killed herself.

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The following test, framed for testing salesman, and closely parallel to one of the army tests, is given by Bruce Barton in the *American Magazine* for March, 1919. There is a time limit set as an index of mentality of different grades. For example, "to take less than 100 seconds is to be in the superior 25 per cent." The individual is graded also on accuracy. The test plainly calls for variegated mental behavior, such as close observation, the ability to hold several things in mind at once, careful and quick use of one's judgment, etc.

With your pencil make a dot over any one of these letters F G H I J and a comma after the longest of these three words: boy mother girl.

Then, if Christmas comes in March, make a cross right here but if not, pass along to the next question, and tell where the sun rises. . . . If you believe that Edison discovered America, cross out what you just wrote, but if it was some one else, put in a number to complete this sentence: "A horse has feet." Write yes, no matter whether China is in Africa or not; and then give a wrong answer to this question: "How many days are there in a week?" Write any letter except g just after this comma, and then write no if 2 times 5 are 10 Now, if Tuesday comes after Monday, make two crosses here; but if not make a circle here or else a square here Be sure to make three crosses between these two names of boys: George Henry. Notice these two numbers: 3, 5. If iron is heavier than water, write the larger number here, but if iron is lighter write the smaller number here Show by a cross when the nights are longer; in summer? in winter? Give the correct answer to this question: "Does water run uphill? and repeat your answer here Do nothing here ($5 + 7 =$ ), unless you skipped the preceding question; but write the first letter of your first name, and the last letter of your last name at the end of this line:

There is need for improvement in the general intelligence tests both in their character and in their use. Thorndike points out the fact that they are not, as their name might indicate, tests of "all intellectual abilities," but only of such abilities as are involved "in learning from lectures and books and dealing with ideas and symbols." He says, illustrating his point:

In the army test Alpha, a test whose data are largely words and numbers and whose score is largely determined by speed, stenographers and typists score enormously better than tool makers, gunsmiths and locomotive engineers, etc., and almost on a level with civil and mechanical engineers and physicians.

It is his opinion, therefore, that "our present standard tests of intelligence need to be greatly extended and improved; and expectations from them need to be kept modestly in line with the facts." One other caution may be appended, namely, that not even vocational psychology can do more toward guiding

the individual in choosing a vocation than to point out the direction in which it appears his nature will block the way with least physical and mental and temperamental handicaps. He may have sufficient unmeasurable will power, or tenacity, or grit to succeed though he goes into a vocation for which he seems least fitted, but he can hardly succeed so well.

Finally, it may be said that the thing which holds out the most promise for the actual realization of the vocational psychologist's dream is the increasing establishment in educational institutions of a personnel bureau, corresponding to a similar bureau in the Army. This will give vocational guidance an official standing, and all the means and methods available will be laid hold of and be turned to account or thrown overboard. The bureau will make use not only of the technique at hand, but "will initiate and encourage research" to the end that trade (vocational) tests may be adapted and invented, the general intelligence tests "be expanded and improved," and other things be done that through vocational guidance "the pupil (and the student) may be helped to discover his own capacities, aptitudes, and interests, may learn about the character and conditions of occupational life, and may himself arrive at an intelligent vocational decision."

THE USE OF MODELS IN THE INTERPRETATION OF DATA FOR DETERMINING THE STRUCTURE OF BEDDED ROCKS

MAURICE G. MEHL

Of the various ways to describe the structure of sedimentary beds graphically, that of showing the configuration of the datum bed by contours is by far the more common and, for most cases, altogether the more satisfactory method. Ordinarily the structural contour map is drawn from irregularly scattered observations—elevations on a *key bed* or on other horizons from which the elevation of this bed may be calculated.

At best the determination of the structure of a region is an approximation. It is rare indeed that a single bed has unlimited exposures over a large area and even with supplementary observations from sub- and superadjacent beds, within a comparatively large proportion of almost any region, no data are to be had. Usually, then, the observations are closely crowded along the limited outcrops and are relatively far apart over most of the area.

Although in general the principles of contouring topography and structure are the same, the details are somewhat different. Since topographic contours attempt to represent accurately the configuration of a surface, every point on that surface is a valid observation and the greater the number of observations the more accurate the resulting contour map. In contouring the structure, although the contours represent a certain condition of the bed it is not the configuration of its surface. What is to be shown is the *structural attitude*, the attitude of the *general plane* of the bed as it has been modified by diastrophism alone. This is not necessarily the upper or lower surface nor even the present attitude of the general plane of the bed as is pointed out later.

One cannot always be sure, for instance, that an elevation on a bed indicates its structural attitude. Within a region of even moderate relief, if the rock series has the normal complement of shales, there is abundant opportunity for their creep or slump with a consequent down-slope bending of the competent beds. One has only to observe this tendency of limestones to conform to the slope of the hill, as it is shown in a fresh cut across a ridge, to realize the possibility of error in this direction.

As a rule, the top of some conspicuous bed is selected as the datum plane and the observations are confined to this horizon as fully as possible. Few beds maintain their full thickness for any considerable distance, however, and often they are notably irregular. In Wilson County, Kansas, the writer has observed the Stanton limestone reduced from more than 30 feet in thickness to nothing within comparatively short distances. Or again, in Anderson County, Kansas, a Sub-Allen limestone which forms a conspicuous cap of as much as 40 feet in thickness over the ridges of a considerable area is very thin or entirely lacking within half a mile from what is essentially its greatest development.

Obviously, closely spaced observations on such an irregular surface do not give a true picture of the structure of the region. If the datum horizon is displaced 5 feet by slump or the irregular surface of the bed, a decidedly abnormal dip is indicated between this point and another observation point nearby which is taken on the properly related plane. An error of 5 feet if distributed over a large distance is not far from the true configuration of the datum bed. It would appear that observation points can be spaced too closely for the accurate determination of the structure.

There is also some question as to the desirability of showing other than the larger features in the configuration of the beds in an attempt to show the structure. Even if one could be sure of the correctness of the closely spaced observations it is doubtful if the minor changes in dip which these observations show would affect the generally parallel beds at any appreciable distance above or below the datum bed.

Granting, however, that all the observed elevations do indicate the true *effective structure*, there is no assurance that the data will be interpreted in a like manner by two different workers. In the writer's experience, a dozen students using the same data will present nearly as many variations in the interpretation of the structure. With common methods there seem to be always several possible interpretations of the same data, although but rarely more than one logical interpretation presents itself if the observation points are in any sense adequate.

An excellent illustration is to be found in a discussion by K. C. Heald.¹ In this discussion it is pointed out that two

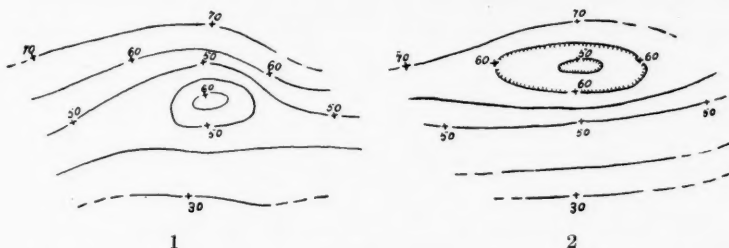


Fig. 1. Structural contour map of a region in which data are lacking at certain critical points. Cross marks with figures are observation points on the datum bed. (After Heald.)

Fig. 2. Structural contour map of the same data as presented in figure 1. Under the methods commonly employed this almost opposite interpretation of the data is permissible if not even logical. (After Heald.)

almost opposite interpretations may be made from the same data. Figures 1 and 2 show the same elevations with an entirely different interpretation. Aside from the fact that the structure shown in figure 2 is a very exceptional expression of deformation, there is apparently no reason why either of these interpretations might not be considered correct.

In determining the structure of a region much must always be taken for granted. It is assumed, for instance, that between two adjacent observation points the dip is essentially uniform. This

¹ Geologic structure of the northwestern part of the Pawhuska Quadrangle, Oklahoma. U. S. G. S. Bull 691 C, p. 80-81, 1918.

assumption is necessary if one is to avoid a number of interpretations comparable to the whims of the various workers. Furthermore, this is found to be justified within limits by experience. It is only because of the fact that the datum plane is thought of as a series of intersecting planes, each one comparatively large, that it may be in any sense adequately represented by contours.

For all practical purposes any surface, no matter how irregular, can be resolved into a series of planes. If the surface is curved at

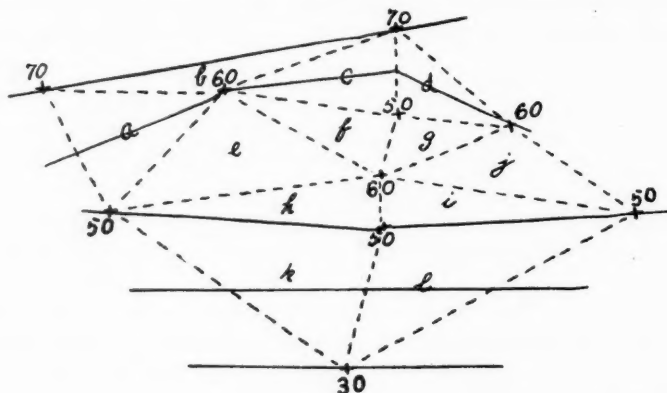


Fig. 3. Application of the *triangle system* to the data presented in figures 1 and 2. The letters A to L indicate the triangles into which the surface is divided by dashed (continuous lines where the edge of the triangles is coincident with a contour) lines. The continuous lines are the contours that appear on the unwarped triangular surfaces.

every part, as in a sphere, the closest representation by planes is that of the greatest number of planes each of the least extent. Three points on a plane, providing they are not in a straight line, fix the position of that plane. If, then, lines are drawn to connect each of three adjacent observation points on a datum bed, that bed will be divided into a series of triangular planes, the greatest number of planes which the data permits. If it is agreed that each set of three points fixes the position of an essentially flat plane which they outline, and this agreement is

arbitrarily adhered to, there can be but slight variation in the interpretation of any structure represented by a series of isolated elevations.

In figure 3, as in figures 1 and 2, the same data are again utilized, but here the principle of intersecting planes is recognized. The observation points are made to outline the several triangular planes *A* to *L*, and each plane is contoured independently. The attitude of the triangles *A*, *B*, *C*, *D*, *K*, and *L* is evident. It is further evident that the "50" corners of the triangles, *C*, *D*, *F*, and *G* are tilted down to form an inclosed depression. Likewise, the point represented by the "60" corners of the triangles *E*, *F*, *G*, *H*, *I*, and *J* represents an elevation. It is obvious then, that there can be but one interpretation of the

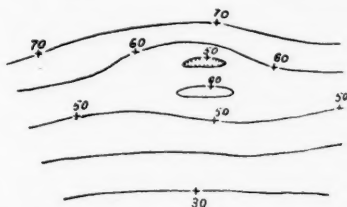


Fig. 4. Structural contour map of the same data as that presented in figures 1 and 2 as it would appear after the sharp intersections of the triangular planes have been "smoothed out."

gross structure of the region. The only possible error is that in the variation in size and the exact position of the small depression marked by the 50 foot contour and the small elevation encircled by the 60 foot contour.

The division of the surface into triangles either graphically or mentally gives the resulting contours a decidedly "stiff" or mechanical appearance. It is evident that the planes must be warped and their intersections "smoothed out" so that any cross section except where broken by faulting shall be free from abrupt changes in direction.

For some time the writer has been practicing a system of modeling which includes all the advantages of the *triangle system* and at the same time eliminates most of its crudities.

THE CONSTRUCTION OF STRUCTURE MODELS

As a first step in the construction of the model a base sheet is prepared from the plane table sheets. The observation points are properly located and the elevation of the datum plane indicated at each observation. The sheet is attached to a soft board and at each observation point a peg is driven so that its length represents the elevation of the bed at that point. Obviously the

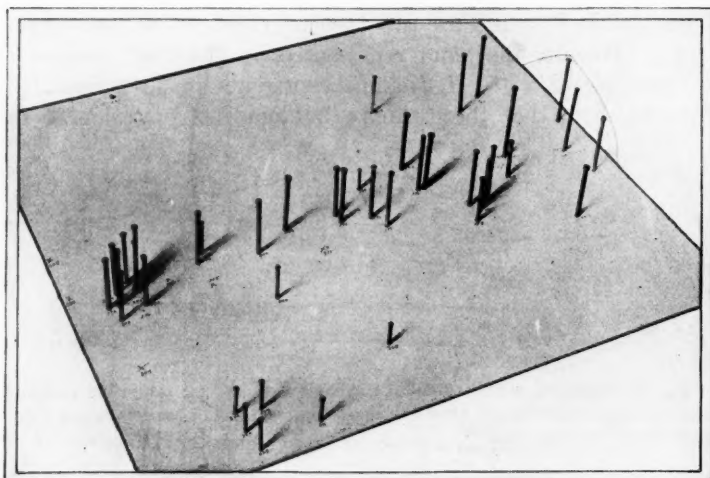


Fig. 5. "Peg" model of the data utilized in the construction of the structure map in Plate XX.

board represents a horizontal reference plane the elevation of which is anything the worker may choose, usually slightly less than the lowest observation point.

After all the pegs are fixed it is a comparatively simple matter to model the surface which they represent by filling in to their tops with fine moist sand or modeling clay. The resulting surface is full of crudities for it is composed of a series of flat triangular surfaces extending between each set of three adjacent points. By slight additions of material in places and the re-

removal of some of the filler in others the surface soon shapes itself into one of broad curves simulating those of the average deformed beds.

There are many short cuts in the technique of model making with which the worker will become familiar after a little practice. The relation of the vertical to the horizontal scale makes no essential difference for if the work is accurately done the resulting contours will always be the same. Obviously, the model must be contoured with the same vertical scale as that used in its construction and the contours must be reckoned and numbered in reference to the assumed elevation of the wood base. The writer has found that on the average a vertical scale which gives a relief of about 3 inches to a model with a base of 16 inches is very desirable. This makes convenient the use of a horizontal scale of 2 or 4 inches to the mile, the usual scales used in plane table work. The models of this size or in units of this size permit the representation of 16 or more square miles, about the average involved in the report of the consulting petroleum geologist.

It is often desirable to preserve the model in the form of a plaster cast. In making casts, care should be taken to preserve the proper relations between the horizontal reference plane and the surface representing the structure. Perhaps the most simple way of accomplishing this is to level the base and then make the negative by pouring plaster of paris over the model (which has been confined by sides of suitable height) till the plaster entirely covers the sand and in its liquid state forms a level surface. When the negative is reversed, insulated, and confined within a suitable frame, the positive may be poured and if the lower side of the reversed negative is horizontal the liquid plaster of the positive will form a flat surface with which the structural surface will have the proper attitude. It has been found that for most work a thin soft soap makes the best insulation between negative and cast.

For contouring the writer has found very convenient an apparatus such as that shown in figure 6. A less elaborate outlay answers the purpose well and is, perhaps, even more accurate.

A long stick with a hole the size of a pencil bored at midlength may be moved about in a plane formed by the edges of a frame about the model and somewhat higher than the latter. The pencil, if fitted closely, may be "set" at the proper distances above the base of the model and the corresponding contours traced.

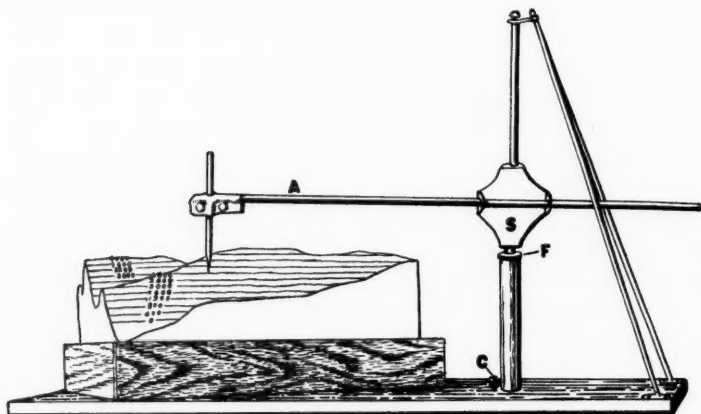


Fig. 6. An apparatus for contouring models and illustrating the use of contours. Constructed in the laboratories of the department of geology, Denison University.

ADVANTAGES OF THE MODELS

Contrary to what might be expected, the models promote speed of contouring the field data. The average data may be modeled and contoured and the contours transferred to paper or tracing cloth in less time than is usually required to puzzle out the best interpretation after the ordinary manner.

The model has been found an excellent aid not only in visualizing the data for the geologist but in explaining the nature of the configuration of the beds to those not familiar with contours. As a sales argument, several oil companies have found the models invaluable.

Aside from these advantages, the models have a distinct phase of usefulness. It is recognized by all geologists that some of the data are at times more or less questionable. It is sometimes impossible to determine in the field whether beds have been properly correlated or whether an outcrop shows the true structural attitude. When the structural data of a region are modeled indiscriminately, it is not uncommonly found that certain of the observation points are decidedly out of harmony with those nearby. In other cases there is evident a distinct offset in the surface represented by adjacent sets of observations. It is at once suggested that the elevations of the adjacent regions have been taken on different beds, beds that have been correlated as the same, or the offset may be of such a nature as to be highly suggestive of a fault which was not recognized in the field. In this manner then, the modeling offers a further check on the field valuation of the observation points.

Of special benefit are these suggestions in the interpretation of well-log data. One recognizes the difficulty of interpretation of such data because of the personal equation injected into the record by the driller.² His record, if not actually compiled from memory at the end of his tower, is based on the hardness of the materials as indicated by the difficulty of drilling, the color of the sludge and, very rarely, the actual examination of the cuttings. Any fall of material in an "open hole" will modify his record materially and his estimates of the thickness or depth of any formation rarely fits well with the steel tape check.

An illustration of the manner in which the models may be useful is found in checking the data given in connection with the structural map of the Bothwell-Thamesville oil district of Canada.² This map, reproduced with slight modifications in plate XX, shows a portion of the structure which has evidently been contoured from well log data from which has been determined the varying elevation of the Delaware limestone. It is clear that unless other data were available than those mentioned by its author, there are many phases of the map which

² Williams, M. Y., Oil prospects of Southwestern Ontario, Canadian Dept. Mines, Summary Rept., 1917, pt. E, plate 1.

can not be looked upon as securely established. True, the author of the map has recognized this to some extent, as is indicated by the many dashed contours. Still, there may be questions as to the correctness of interpretation of some of the data in the more definite portions of the map such as the extremely long, narrow syncline near the center of the plate. Apparently there is but a single observation upon which this is based notwithstanding the fact that it is decidedly out of keeping with the regional structure.

There is another striking peculiarity in the manner after which the contours follow the outlines of the "oil pools" in all their sinuosity. One recognizes the common tendency to interpret all data so as to favor a "suitable structure" about producing wells and is inclined to wonder if this is another illustration. Certain it is that so extensive a coincidence of the outline of the oil pools and the contours is out of the ordinary.

The data indicated in this map has been modeled in recognition of the intersecting triangular plane method and the resulting contours are shown in red on plate XX.

In constructing the model all of those observations that were designated as "uncertain" have been omitted because in one case on the original map the elevation of the datum plane varies over 40 feet from the observed "uncertain" elevation. While it cannot be asserted that the resulting contours accurately record the structure of the region, there can be no question but that they do show, with possible minor variations, the most logical interpretation of the data utilized if we are to assume that the data are all valid. As a matter of fact, several of the observations appear decidedly out of harmony with the general attitude of the beds and should call for the most strict investigation in the field before adopted. One striking example is the single elevation upon which the conspicuous, inclosed depression near the east center of the map is based.

Now while the possibility of eliminating questionable data has been pointed out, it must be recognized that there is great danger in this easy elimination. It must be done with the best discrimination and only after the closest study and after the sug-

gestions have been carefully verified in the field. Otherwise, obviously, there would be a very natural tendency to eliminate all data which did not make for a structure corresponding to the preconceived ideas of the worker. It may be added, however, that on nearly all occasions where the models have seemed to demand the rejection of certain data the further investigations in the field have justified this elimination.

PLATE XX

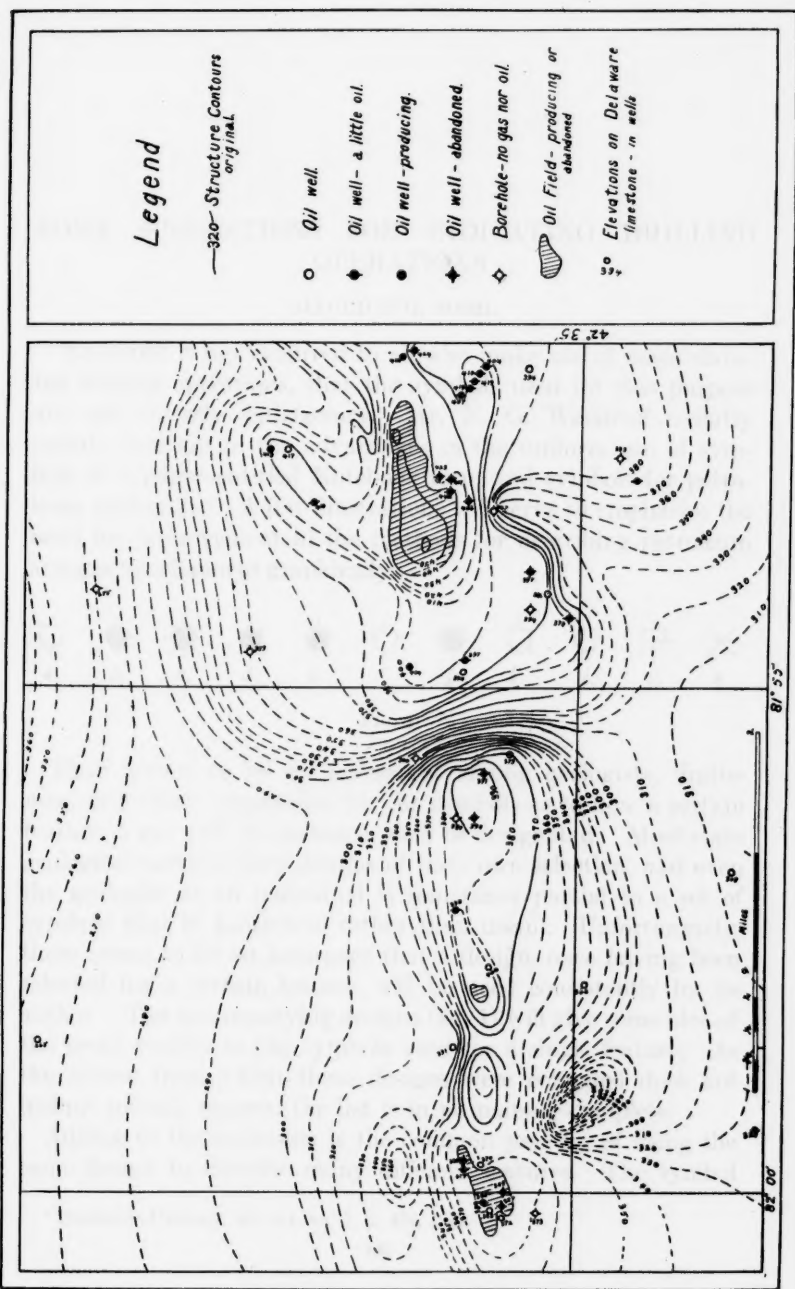
Structural contour maps to illustrate the difference between the common methods of interpretation of structural data and the use of models for this purpose.

—200— Structure Contours
from maps



Prosser, Ohio

ESLEIGH, MFG.





SOME SUGGESTIONS FOR INDICATING DRILLING OPERATIONS

MAURICE G. MEHL

No doubt it has occurred to all who make use of maps showing drilling operations, that the symbols used for this purpose are not entirely satisfactory. Mr. E. G. Woodruff recently called attention to the advantages in the uniform use of symbols in a paper entitled Notebook form and symbols for petroleum geologists.¹ A few illustrations will serve to emphasize the need for improvement in the methods for describing petroleum and gas development graphically.



FIG. 1

There seems to be no agreement among geologists, draftsmen, and others responsible for the symbols as to how a certain feature, a gas well, for instance, shall be designated. Most state geological surveys have designs of their own selection, and even the geologist as an individual is sometimes partial to a set of symbols that is distinctive rather than useful. Unfortunately, there seems to be no assurance that a design, once having been selected for a certain feature, will be used consistently by its author. The accompanying designs (fig. 1) will give some idea of the great variety in the symbols used for a single feature. As the source from which these designs were compiled does not include private reports, the list is in no manner complete.

Adding to the confusion is the common practice of using the same design to describe many different features. The symbol

¹ *Economic Geology*, vol. 14, no. 5, p. 424, 1919.

for a gas well, for instance (fig. 1, d), has been used in published reports alone to indicate fully a dozen different conditions such as "Gas well," "Abandoned gas well," "Water sand," "Oil well spoiled," "Stopped above sand," etc.

Any set of symbols, if it is to be universally adopted, must satisfy certain strict requirements. Most of these qualifications are obvious, but certain of the more important are reviewed herewith.

SIMPLICITY OF DESIGN

Simplicity is undoubtedly one of the most important considerations. In the first place, to be most useful, the symbols must involve the fewest possible number of lines. A complicated design will not permit the reduction that is often necessary or desirable. When it is realized that there are occasion-



FIG. 2

ally over one hundred wells within a square mile, and that it is not uncommon for maps to be reproduced on a scale of one inch to the mile or less, there can be no doubt but that many designs in common use are not well fitted for all scales.

Even though the maps are reproduced on a sufficiently large scale, the designs are often so complicated as to appear very similar and are, therefore, readily confused in a cursory glance. Designs that depend for their distinctness on the difference in length of component lines or the addition of a ray to a many rayed figure are not desirable. Clearness of design is closely associated with the numbers of lines involved.

To obtain clearness of design some have adopted a set of distinctive figures such as circles, squares, crosses, pentagons, etc. While such figures stand out conspicuously for the most part, they are far from mechanically simple. As a rule they involve "irregular angles" and a large number of operations.

Distinctive, but mechanically complex, designs are shown in figure 2. Any attempt to use these symbols on a large scale requires a great amount of labor or reduces the drawing to freehand work, which is, as a rule, quite unsatisfactory.

FLEXIBILITY

To be of greatest use, a map showing oil and gas development must be kept up to date. In order that development which is today designated as a location may be changed to an oil or gas well or a dry hole when the test is completed and may be indicated as an abandoned producer at a later time, each symbol used must be such that by simple additions it may be changed to any other design that might be required in the normal history of the well.

LOGICAL DESIGNS

Any development map is likely to show a considerable number of different features. In reality, however, the information conveyed comes under one of three large heads: producing wells, nonproducing wells, and locations. Each of these types requires a distinct symbol, and inasmuch as a producer is predominantly either oil or gas, a distinction must be made between these two. The result is that four primary symbols form the basis for all designs that may be required.

Very commonly a well produces both oil and gas. The symbols for each must be such that they can be combined readily so as to produce a single, self-explanatory figure. The addition of half the symbol for a gas well to that of an oil well tells clearly that the producer is predominantly an oil well but with an appreciable amount of gas. Or again, the combination of the total essentials of the oil and gas symbols should convey the information that the oil and gas are equally divided in the well.

Nonproducing wells may be dry holes or abandoned producers. The reasons for nonproduction may be of great variety, and it is often desirable to record these reasons. It is important to know, for instance, that oil in quantities too small to be recovered

with profit, has been struck. The essential idea is that the well is a nonproducer, however, and the nonproduction symbol must be utilized. The proper designation for such a condition is logically half the symbol for an oil well plus the symbol for a nonproducer.

A dry hole is logically a combination of the symbols for a location and nonproduction. It is true that many other details concerning a dry hole are interesting and often important, such, for instance, as the presence or absence of a sand, the nature of the sand, the presence or absence of water, the adequacy of the test, etc. It is very doubtful, however, whether such details should be recorded on a development map except in the most special cases. As a rule the map is a compilation from many sources and not the record of the compiler's direct observation of the drilling. To be of real value, the statement that a certain dry hole does not mark an adequate test, reasons for this conclusion are necessary. Apparently a written explanation is more desirable than a special symbol for many of the details concerning a nonproducing well.

"Location" usually means actual drilling or good evidence that drilling will be started soon—the erection of a drilling rig, for instance. Very often a map is well marked with "locations" which are to be construed as meaning that they will become drilling locations in the ordinary sense if the "drilling well" proves profitable, if more stock is sold, or if the fancy of the operator does not change; very indefinite locations at best, and usually calculated to mislead the uninformed. If it is desirable to distinguish between actual drilling locations and prospective tests, it is probably well to use a definite symbol for a drilling well and portions of the same symbol to designate the varying degrees of probability that drilling will be carried on seriously at a later time.

THE UNI-COLOR SYSTEM

A great variety of simple symbols is to be had by the use of colors and in many cases a multi-color scheme is employed to good advantage. In most "pin systems" for keeping a record

of development on wall maps, pins with heads of various colors show in a striking manner the trends of production. It is clear, however, that for a set of utility symbols a multi-color system cannot be used successfully, because the cost is in many cases prohibitive, and because in the common reproduction by blue-printing or photography, only black and white symbols may be utilized.

<i>Location.</i>	○ <i>Inadequate Test.</i>	⊙
<i>Dry Hole.</i>		⊘
<i>Show of Oil.</i>		⊗
<i>Oil Well.</i>	● <i>The Same - Abandoned.</i>	⬤
<i>Show of Gas.</i>		⊗
<i>Gas Well.</i>	⊙ <i>The Same - Abandoned.</i>	⊙
<i>Oil Well with Show of Gas.</i>	● <i>The Same - Abandoned.</i>	⬤
<i>Oil and Gas Well.</i>	● <i>The Same - Abandoned.</i>	⬤
<i>Gas Well with Show of Oil.</i>	⊙ <i>The Same - Abandoned.</i>	⊙

FIG. 3

THE SUGGESTED SYMBOLS

In figure 3 is suggested a set of symbols thought to fulfil adequately the requirements as outlined above. There is no radical departure from the present practice, for most, if not all, of symbols are in common use. In one instance, the symbol for a gas well, it has been necessary to alter a generally accepted design. However, inasmuch as the essentials of the design are the same and certain complications are avoided, the change should

not be annoying. Especially is this true in that the substitute design requires fewer operations. All are mechanically simple and require but a few operations. They are in a very real sense self-explanatory and logical, and are of such a nature as to be reproduced readily on either large or small scale.

The "Inadequate Test" symbol of figure 3 illustrates the type of variation from the generalized "dry hole" symbol which permits the indication of a large number of details. By the substitution of such letters as W, C, and N, details like "water sand," "close sand," "no sand," etc., are recorded. Regardless of the detail indicated by the letter, the essentials are the same—a nonproducing well in which neither oil nor gas was encountered in appreciable quantities.

Frequently it is desired to distinguish between wells producing at different horizons. It has been the writer's experience that this and similar data can be shown with less confusion by placing a Roman or an Arabic reference numeral against the regular symbol than by the use of special designs such as have been suggested.

THE KIMMSWICK AND PLATTIN LIMESTONES OF NORTHEASTERN MISSOURI

AUG. F. FOERSTE

1. THE TERMS PLATTIN AND KIMMSWICK AS USED IN THE GEOLOGY OF MISSOURI

The Champlainian or Mohawkian strata of Missouri may be divided into two major lithologic divisions: a lower very fine grained limestone in which usually no individual grains can be recognized even with the assistance of a lens, and an upper, distinctly granular limestone which at some horizons is even coarsely granular, and more or less crystalline.

In the *Geology of Missouri*, published by Prof. E. B. Branson in 1918 as number 15 of volume 19 of the *University of Missouri Bulletin*, the lower fine grained limestone is identified as the Plattin formation, while the overlying distinctly granular limestone is identified as the Kimmswick limestone, both names being applied in a much less restricted sense than that advocated at present by E. O. Ulrich, the original author of these names. This will become evident on referring to plate 2 among the *Correlation Tables* at the close of Bassler's *Bibliographic Index of American Ordovician and Silurian Fossils*, published in 1915; a part of this table is reproduced in a modified form on one of the following pages in section 6 of this paper.

2. THE LITHOLOGICAL CHARACTERISTICS OF THE PLATTIN AND KIMMSWICK LIMESTONES

The lower or Plattin limestone appears to have originated as a lime mud deposited as the result of chemical action induced by bacteria. During the deposition of these lime muds quiet waters evidently prevailed. This is shown by the frequent preservation of even the most minute details of surface sculpture on brach-

iopods, trilobites, and other fossils, and by the frequency with which free cheeks are found still attached to the cranidia of trilobites, even the thoracic segments sometimes being present. There is no evidence in these strata of shells having been swept by currents into unnatural positions. There is no evidence of material distinctly of elastic origin. No ripple marks cross the surfaces of the limestone layers, although there is no reason why small ripple marks should not appear locally.

The upper or Kimmswick limestone evidently is chiefly of clastic origin, and might be defined as a lime sand formed by the comminuted remains of shells, bryozoans, and other organisms, more or less altered by crystallization. In the more coarsely granular layers, irregular bedding and cross bedding is not uncommon. Trilobite remains almost invariably are dismembered and more or less broken. The more strongly comminuted organic remains form a matrix in which many other fossils are imbedded. It is remarkable how frequently the surfaces of the imbedded fossils are well preserved. It is evident that comminution of organic remains into lime sand preceded the washing of these sands over the imbedded fossils sufficiently to prevent the surfaces of the latter from being strongly abraded. Periods of comminution and of aggradation of lime sands may have followed each other more or less alternately, or the particles comminuted in one area may have been swept by currents into other neighboring areas.

3. THE FOLLEY, BRYANT, AND MCCUNE LIMESTONES, OF KEYES

The first attempt to classify the Champlainian or Mohawkian strata of Missouri and to apply geographical names to their major divisions was made by Prof. C. R. Keyes in 1898, in a paper on Some Geological Formations of the Cap au Gres Uplift, published by the Iowa Academy of Science. In this paper the term Bryant limestone is used for the upper part of the limestone included by Branson in his Plattin formation, and the term Folley is used for the lower part of the same formation. The name

McCune was used for the upper or Kimmswick limestone, as the latter term is used by Branson in the same area.

The term Bryant limestone includes the very fine-grained light blue, relatively thin-bedded, richly fossiliferous limestone, which not only contains a Lowville fauna but also has a Lowville aspect lithologically. The type exposures are along Bryant Creek in the northeastern part of Lincoln County. The total thickness of the Bryant limestone was estimated by Keyes as between 140 and 150 feet. Only the top of this Bryant limestone was studied in Ralls County by the present writer.

The Folley limestone includes the underlying light yellow, heavy, magnesian, poorly fossiliferous limestone. The type locality is Folley, also spelled Foley, a railroad station a short distance north of Winfield, in the eastern part of Lincoln County, where the limestone is exposed in the bluffs west of the Mississippi River. The thickness of the Folley limestone was estimated by Keyes as 65 feet, but later it was recognized that the actual thickness is considerably greater. In Ralls County the Folley limestone is exposed north of the bridge 2 miles northwest of Frankford, on the pike to New London.

Keyes evidently intended to use the term McCune for all of the distinctly granular limestone of Champlainian age occurring above his Bryant limestone. This would make the term McCune equivalent to Kimmswick in the broader sense in which the latter is used by Branson. The type locality is near McCune station, about half way between Frankford and Bowling Green, in the northwestern part of Pike County, the exposures occurring on Peno Creek, directly west of town, where a long bluff lines the eastern side of the creek. The abundance of *Receptaculites oweni* associated with *Hormotoma major* suggests that the actual exposure west of McCune station is limited to the lower part of the upper half of the Kimmswick limestone of Branson, but does not rise as high as the top of the latter. Keyes at first assigned a thickness of only 25 feet to his McCune limestone, and raised this later to 50 feet, but it is known now that the Kimmswick limestone of Branson reaches thicknesses varying from 100 to 125 feet at several points in Ralls County, the county immediately north of that in which the typical McCune outcrops occur.

4. THE TERMS PLATTIN AND KIMMSWICK PROPOSED BY ULRICH

The terms Plattin and Kimmswick were introduced by E. O. Ulrich, and made their first appearance on page 111 of the report of the Missouri Bureau of Mines, 2nd series, volume 2, published in 1904. Here it is stated that the term Kimmswick is proposed for the crystalline limestone exposed at Graysboro, Cape Girardeau, Glen Park, and Kimmswick, and that the term Plattin was to be used for the strata between the Kimmswick and the so-called First Magnesian limestone farther down. Kimmswick is near the northeastern corner of Jefferson County, about twenty miles southwest of St. Louis; the type exposures extend from Kimmswick 8 or 9 miles southward to Riverside. Plattin Creek traverses the southeastern corner of the same county, and is about 18 miles from Kimmswick.

5. THE AUBURN CHERT STUDIED BY BRANSON

In 1909, Prof. E. B. Branson made a special study of the fauna of the chert occurring in the very fine-grained limestone in the vicinity of Auburn, a village in the north-central part of Lincoln County, about 6 miles south of its northern boundary, and probably about the same distance from the type exposures of the Bryant limestone. Although apparently of about the same horizon as the Bryant limestone, the fauna studied by Branson has gone into literature as that of the Auburn chert.

6. CORRELATION TABLES

The terms McCune, Auburn, Bryant, and Folley were founded on exposures in the northeastern counties of Missouri, in Pike and Lincoln Counties. The terms Kimmswick and Plattin were drawn from localities in the southeastern counties of the same state, both in Jefferson County. In Branson's *Geology of Missouri* the terms Kimmswick and Plattin have been extended so as to cover also the exposures earlier defined as McCune, Bryant, and Folley, in the northeastern counties of the state. Judging from the Correlation Tables published in Bassler's Index, Ulrich

and Bassler prefer to use the terms Kimmswick and Platin in a more restricted sense. A modification of a part of one of their tables is presented here in the following form:

KENTUCKY	SOUTHEASTERN MISSOURI	NORTHEASTERN MISSOURI	MINNESOTA AND NORTHERN IOWA	BRANSON'S GEOL. OF MISSOURI
		McCune	Stewartville	Kimmswick
Curdsville		Prosser	Prosser	
	Kimmswick			
Clay shale		Auburn	Decorah	Plattin
Tyrone	Plattin	Bryant	Platteville	
Oregon		Folley		

The preceding table suggests that in Champlainian times northeastern Missouri formed part of the northern Mississippi valley province, including Minnesota, Wisconsin, and northern Iowa. While considerable lithological differences are noted in passing from northern Iowa across a long gap into northeastern Missouri, a considerable part of the northern fauna may be still recognized as far south as northeastern Missouri. It is not certain, however, that the typical Kimmswick fauna of southeastern Missouri passes across the gap in northern Warren and southern Lincoln Counties into northeastern Missouri. This can be determined only after it has been ascertained definitely what are the characteristics of this fauna, not at Thebes but at Kimmswick, the type locality. Bassler lists only 4 species from the Kimmswick: *Comarocystites shumardi*, *C. obconicus*, *Echinospaerites aurantium*, and *Eurydictya calhounensis*. None of these species is known at Kimmswick, and the first three are regarded as belonging beneath the lowest strata exposed in the Thebes section.

If in Champlainian times there was an east and west barrier across the central part of Pike county in the area now traversed by the Cap au Gres fault, such a separation of northern and southern faunas might have been operative at various times and

in varying degrees. It may be noted, for instance, that the characteristic cystid, *Comarocystites shumardi* (see 4 in Description of species), described from the Kimmswick of Cape Girardeau, in southeastern Missouri, was found by the writer also in the large quarry northwest of West Kimmswick, 85 miles northwest of Cape Girardeau, but the most diligent search failed to reveal this fossil in Pike or Ralls County, in northeastern Missouri. Moreover in Bassler's Index, *Echinosphaerites aurantium* is listed from the Kimmswick of Missouri, presumably from Cape Girardeau in the southeastern part of the state, but no trace of this fossil has been found in the northeastern part of that state.

7. STUDIES OF ONLY ONE LOCAL AUBURN AND ONE LOCAL KIMMSWICK FAUNA PUBLISHED SO FAR

Unfortunately, only two studies of the Champlainian faunas here under consideration have been published so far. The first of these is a detailed study by Prof. E. B. Branson of the fauna of the Auburn chert, as exposed along a road side east of the village of Auburn, in the north central part of Lincoln County. This study was published in 1909, in volume 18 of the Transactions of the Academy of Science of St. Louis. The following year, in 1910, Prof. T. E. Savage published a detailed study of the stratigraphic succession of the faunal elements of the Kimmswick limestone as exposed along the Mississippi River, three-fourths of a mile south of Thebes, in Illinois. This famous locality is only about 6 or 7 miles southeast of Cape Girardeau, on the Missouri side of the Mississippi River. Both of these studies are confined to single formations as exposed at single localities. No corresponding faunal studies have been published of the McCune, Prosser, Plattin, Bryant, or Folley limestones of Missouri or of the adjacent parts of Illinois.

8. RECENT STUDIES OF CHAMPLAINIAN FAUNAS IN NORTHEASTERN MISSOURI

Recently the writer took advantage of an opportunity to study in more or less detail several horizons among the Champlainian rocks of Ralls County and of the adjacent parts of Pike County, Missouri. These horizons included all of those included by Branson under the term Kimmswick, used in the broader sense. In addition, only the top of the underlying Plattin limestone was studied with any care. No fossils were found in the overlying Buffalo or Maquoketa clay shales in those parts of Ralls County where these shales were present. At most localities in this county, the Kimmswick of Branson is overlaid directly by the Devonian. Farther southward, in Pike County, the Maquoketa is sparsely fossiliferous.

In the area under investigation, the Champlainian strata are exposed along the Salt River and its tributaries. Since interest was centered chiefly on the Kimmswick limestone, using this term in its broader sense, this limestone will be discussed first.

9. THE FAUNA OF THE KIMMSWICK LIMESTONE, SOUTH OF THEBES, ILLINOIS

About three miles south of Thebes, Illinois, there is a conspicuous exposure of crystalline limestone along the east bank of the Mississippi River. The fossils listed by Professor Savage from this locality are recorded in the accompanying table. Section *a* begins at water level, and section *o* occupies the highest position stratigraphically. The thickness of the different parts of the section is recorded in the table in feet and inches. A total thickness of almost 70 feet of strata is exposed. Of this thickness the lower 20 feet includes the more fossiliferous portion, to which the overlying 50 feet apparently does not contribute any new important faunal element.

It will be noted that neither *Comarocystites* nor *Echinosphaerites* are listed by Savage from this Thebes locality, although both occur at Cape Girardeau, and *Comarocystites* has been found as far north as the large quarry northwest of West Kimmswick.

This suggests that the Kimmswick south of Thebes and the Kimmswick at Cape Girardeau and at West Kimmswick may not be identical stratigraphically.

The fossils listed in the last column of the table, under the letters *LR*, were obtained on Little Rock Island, northwest of Thebes, and evidently contain about the same fauna as the lower strata examined by Savage at the locality south of Thebes.

10. KIMMSWICK FAUNA IN RALLS COUNTY AND IN NORTHERN PIKE COUNTY, MISSOURI

The exposures at the Henry Hamilton, Big Cave, and Wood Cave localities are in direct contact with the top of the Platin, and represent the lowest Kimmswick exposed in the Salt River area. The lowest exposure along the Sanders branch, locality 1, is supposed to begin about 15 feet above the base of the Kimmswick. Locality 7 forms the top of the section. The rise of the stream channel is at a rate so small that no exact measurements can be made readily and those here furnished, beneath the locality numbers, are mere estimates.

A comparison of the lower part of the Sanders branch section, including localities 1, 2, 3, and 4, with the Kimmswick limestone section south of Thebes, Illinois, shows a considerable similarity of faunas, including such forms as *Clitambonites* sp., *Dinorthis meedsi*, *Dinorthis pectinella*, *Parastrophia hemiplicata* var., *Amphilichas cucullus*, *Ceraurinus* cf. *scofieldi* or *trentonensis*, and *Remopleurides* sp. With this lower part of the Sanders branch section it seems possible to correlate also the Frankford and W. T. Jackson localities, in the northern part of Pike County, owing to the presence of *Dinorthis meedsi* and *Amphilichas cucullus* at the latter localities.

Very little is known of the fauna of localities 5 and 6 of the Sanders Creek section, beyond the fact that *Hormotoma* (?) *major* tends to be more common here, and that various poorly preserved species of *Maclurina*, *Maclurites*, and large forms of *Fusispira* occur here. The limestone at this horizon tends to be more coarsely granular and more crystalline than at other horizons in

the so-called Kimmswick section of Ralls County. The localities at Sugar Creek and at McCune Station, in northern Pike County, evidently belong to the same *Hormotoma* (?) *major* horizon. This *Hormotoma major* zone is the McCune of Keyes, when this term is used in a restricted sense.

The top of the so-called Kimmswick limestone section along Sanders branch is formed by a finer grained limestone containing an occasional poorly preserved *Maclurina* and other fossils known also in the underlying strata. It is overlaid by 5 feet of yellowish clay, followed by 10 feet of fine grained Devonian limestone, an unexposed interval of 7 feet, 6 feet of Devonian sandstone, and a considerable thickness of fine grained Devonian limestone, of which only the lower part is exposed at the locality in question.

At the W. H. Bowles locality, only the top of the Kimmswick is exposed, overlaid by 2 feet of yellowish clay shale, 15 feet of calcareous shale, probably Devonian, and 15 feet of undoubted Devonian limestone. The chief interest at this locality was the presence of a small *Cyclocystoides* near the top of the Kimmswick limestone.

At Hagan's shop, also at three-fourths of a mile east of Shiel, and at a locality a mile northeast of Spalding Springs, all three localities being located along the northwestern line of outcrop of the so-called Kimmswick in Ralls County, Missouri, *Plectambonites gibbosus* occurs in the upper part of the Kimmswick section. The *Plectambonites gibbosus* horizon is regarded as above that of the typical *Hormotoma* (?) *major* zone.

11. CORRELATION OF RALLS AND PIKE COUNTY KIMMSWICK WITH STRATA ELSEWHERE

It has been noted already, on a preceding page, that the strata forming the lower half of the so-called Kimmswick section along Sanders branch may be correlated with those strata south of Thebes, Illinois, which were regarded by Savage as of Kimmswick age. A considerable part of the fossils in these strata occur also in the Prosser of Minnesota, although this may not involve actual identity of horizons.

As far as known, the overlying strata, forming the upper part of the Kimmswick section along Sanders branch, including both the *Hormotoma* (?) *major* and the *Plectambonites gibbosus* zone, are not known to occur south of Pike County. Apparently they are restricted to areas north of the Cap au Gres fault, and have their affinities with the Prosser strata exposed in Minnesota. If *Plectambonites gibbosus* and *Cyclospira bisulcata* are to be regarded as characteristic of the lower half of the *Fusispira* bed of Ulrich, then the highest so-called Kimmswick strata exposed in Ralls County and in the adjacent parts of Pike County do not rise above the Prosser horizons. This view is favored by the extreme poverty of *Maclurites* and *Maclurina* in the upper strata of the so-called Kimmswick in Ralls and Pike Counties.

Since the McCune exposures belong to the *Hormotoma* (?) *major* zone, beneath the *Plectambonites gibbosus* horizon, it appears necessary to correlate the McCune limestone also with the Prosser of the Minnesota section, at least for the present. When a better knowledge of the fauna of the McCune limestone has been secured it may be necessary to alter this correlation.

On the other hand, the lower Kimmswick fauna, containing *Comarocystites* and *Echinosphaerites*, is unknown in Ralls and Pike Counties, in the northeastern part of Missouri. Until this lower Kimmswick fauna is known in greater detail, it must be regarded as practically an uncertain quantity in Champlainian stratigraphy. At present it is assumed to belong below any strata exposed at the locality south of Thebes, Illinois.

12. THE FAUNA OF THE PLATTIN LIMESTONE IN RALLS COUNTY, MISSOURI

No fauna has been listed so far from the typical Plattin limestone of southeastern Missouri. In the northeastern part of Missouri, in Ralls County, only those fossils have been studied which occur in the upper part of the Plattin limestone as there exposed, usually within 10 feet of the top of the formation. On comparing the fauna from the top of the Plattin limestone in Ralls County with that of the Auburn chert in Lincoln County, enough differ-

ences are shown to suggest that they may belong to different horizons. Of the new species and varieties described by Branson from the Auburn chert, only *Parallelodus obliquus* and *Pterygometopus lincolnensis* have been identified more or less doubtfully from the Plattin of Ralls County.

Faunal lists

In the accompanying faunal lists all that is known at present of the faunas of the Kimmswick limestone south of Thebes, in Illinois and in Ralls and Pike Counties, in northeastern Missouri, has been tabulated in order to show the similarity of the Thebes fauna to the fauna of the lower part of the Ralls County section. On the other hand the fauna of the top of the Plattin limestone in Ralls County and that from the Auburn chert has been tabulated in order to make evident certain differences in faunal content.

In the list of fossils from Thebes, the thickness of the strata is indicated in feet and inches; in the list of fossils from Sanders branch, the estimates are in feet. In the Sanders Branch section, horizons 1 to 4 correspond to horizons *a* to *i* in the Thebes section. Horizons *j* to *o* of the Thebes section contain about the same fauna as the underlying horizons of this section. The column marked L. R. records the species found on Little Rock Island, which is located about 2 miles north of Thebes. Horizons 5 and 6 of the Sanders Branch section form the McCune zone of the Kimmswick and are not represented in the Thebes section. In table 14, exposures corresponding to the lower half of the Sanders Branch section are printed on the left side of the Sanders Branch section, while exposures corresponding to the upper half of the latter are printed on the right. The Pike county sections are separated from the Ralls county sections by a darker line.

The numbers preceding the names of some of the fossils in the various lists indicate the order in which these fossils are discussed in the Description of Species, at the end of this paper.

SOUTH OF THEBES, ILLINOIS

	(a) 2-6	(b) 3-2	(c) 2-0	(d) 1-6	(e) 1-9	(f) 3-0	(g) 1-6	(h) 2-4	(i) 4-0	(j) 1-6	(k) 8-6	(l) 4-0	(m) 7-0	(n) 12-0	(o) 15-0	(t. n.) 12-0
Receptaculites oweni.....		X									X					
Clitambonites sp.....		X														
Crania trentonensis.....																X
Crania cf. setigera.....																X
Dalmanella rogata.....		X						X								X
Dinorthis pectinella.....		X						X								X
Dinorthis sp.....		X						X								X
Parastrophia hemiplicata.....		X			X			X					X			X
P. hemiplicata var.....		X			X			X								X
Platystrophia shepardi.....			X					X								X
Plectambonites minnesotensis.....			X					X					X			X
Plectrothis plicatella.....								X								X
Rafinesquina alternata.....		X						X								X
Rafinesquina minnesotense.....		X						X								X
Rhynchotrema anticostiense.....			X					X								X
Rhynchotrema increbescens.....								X					X			X
Scenidium anthონense.....		X														X
Schizambon sp.....			X													X
Strophomena billingsi.....		X														X
Str. emaciata.....			X													X
Str. scofieldi.....		X			X											X
Str. trentonensis.....		X	X					X					X			X
Triplecia sp.....		X														X
Zygospira recurvirostra.....		X	X		X											X
Cyclonema praecipitum.....		X														X
Cyrtolites ornatus var.....								X								X
Holopea pyrene.....																X
Strophostylus textilis.....		X														X
Ambonychia amygdalina.....								X								X
Byssonychia intermedia.....																X
Orthoceras sp.....		X	X		X			X								X
Bronteus lunatus.....					X			X								X
Bumastus orbicaudatus.....		X														X
Bumastus trentonensis.....		X	X		X			X			X					X
Calymene callicephala.....		X														X
Ceraurus pleurexanthemus.....		X														X
Ceraurinus cf. scofieldi.....																X
Illaenus americanus.....		X	X		X			X			X		X			X
Isotelus maximus.....					X			X					X			X
Lichas.....																X
Amphilichas cucullus.....		X	X					X								X
Amphilichas cf. robbinsi.....								X								X
Pseudosphaerexochus cf. vulcanus.....		X														X
Pterygometopus intermedius.....		X	X													X
Remopleurides striatulus.....								X								X
Remopleurides cf. canadensis.....		X														X
Thaleops cf. ovatus.....																X

14. FAUNA OF KIMMSWICK LIMESTONE IN RALLS AND NORTHERN
PIKE COUNTIES, MISSOURI[illegible]

15. FAUNA OF TOP OF PLATTIN LIMESTONE IN RALLS COUNTY

	HENRY HAMILTON	YEAGER	CITY QUARRY	SUSAN KENNEY	BUFORD CAVE	J. H. SMITH	CONN'S FORD	BIG CREEK	NORTH OF SPALDING SPRINGS	ALSO IN AUBURN CHEST
<i>Streptelasma breve</i>							X			
1. <i>Tetradium fibratum</i>		X					X			
3. <i>Cornulites flexuosus</i>	X		X		X	X	X			
<i>Orthis tricenaria</i>		X	X	X	X		X			
<i>Pionodema subaequata</i>		X	X	X	X	X	X	X	X	X
<i>Plectambonites sericeus</i>		X	X	X	X	X	X			
9. <i>Zygospira nicolleti</i>			X							
<i>Rafinesquina alternata</i>					X		X			
<i>Rhynchotrema minnesotense</i> ..					X		X			
12. <i>Schizocrania filosa</i>					X		X	X		
<i>Strophomena incurvata</i>	X			X	X	X	X	X	X	X
14. <i>Trematis huronensis</i>		X			X		X			
15. <i>Zygospira deflecta</i>		X			X		X			
16. <i>Ctenodonta cf gibberula</i>									X	
<i>Ctenodonta nasuta</i>					X					X
<i>Ctenodonta nasuta robusta</i> ...					X			X		
<i>Ctenodonta cf. scotfieldi</i>							X			
<i>Cyrtodonta billingsi</i>						X				X
<i>Cyrtodonta huronensis</i>		X			X					
<i>Cyrtodonta obesa</i>							X			
17. <i>Parallelodus obliqua</i>		X					X			
<i>Clathrospira subconica</i>		X			X		X			
18. <i>Cyrtolites ornatus minor</i>					X		X			
<i>Cyrtolites retrorsus var.</i>		X					X			X
<i>Gyronema duplicatum</i>							X			
<i>Helicotoma planulata</i>		X						X		X
19. <i>Holopea concinnula</i>							X			
20. <i>Holopea cf. parvula</i>							X			
21. <i>Hormotoma gracilis angustata</i>		X	X	X	X	X	X	X	X	X
<i>Liospira obtusa</i>		X	X		X	X	X	X		
<i>Lophospira bicincta</i>			X		X					
<i>Lophospira obliqua</i>					X					X
<i>Lophospira oweni</i>						X	X			X
<i>Phragmolites fimbriatus</i>		X					X			X
<i>Salpingostoma buelli</i>							X			
<i>Subulites conradi</i>		X								
25. <i>Conularia heymani</i> sp. nov...			X		X		X			
26. <i>Conularia</i> sp.....										
27. <i>Hyolithes baconi</i>					X	X				
29. <i>Orthoceras</i> sp.....						X	X			
30. <i>Spyroceras bilineatum</i>		X	X	X	X		X			X
31. <i>Tripteroceas planodorsatum</i> ..			X				X			X
43. <i>Bathyurus spiniger</i>		X	X				X			X
<i>Bumastus milleri</i>					X		X			X
37. <i>Ceraurus plattinensis</i>	X		X		X		X		X	
<i>Isotelus gigas</i>			X				X	X		X
41. <i>Pterygometopus lincolnensis</i> ..					X		X			X
<i>Pterygometopus intermedius</i> ..							X	X		X

16. THE FAUNA OF THE AUBURN CHERT, IN LINCOLN COUNTY, MISSOURI

The following is a list of the species occurring in the Auburn chert, in the vicinity of Auburn, in Lincoln County, Missouri. Almost all of the species mentioned were listed by Professor Branson in his paper on the fauna of this chert, published in 1909. To this have been added those species which in the body of Bassler's Bibliographic Index are cited from the same horizon and locality; and also a few species found by the writer in the quarry a short distance north of Auburn, on the east side of the main pike. Those found in this quarry are italicized. The new species described by Branson are indicated by *.

- | | |
|--|--------------------------------------|
| <i>Hindia parva</i> | <i>Eotomaria dryope</i> |
| <i>Columnaria halli</i> | * <i>Helicotoma missouriensis</i> |
| <i>Lichenaria typa</i> | <i>Helicotoma planulata</i> |
| <i>Streptelasma corniculum</i> | <i>Helicotoma tennesseensis</i> |
| 2. <i>Beatricea gracilis</i> | <i>Holopea insignis</i> |
| <i>Dalmanella testudinaria</i> | * <i>Hormotoma fasciata</i> |
| <i>Orthis tricenaria</i> | <i>Hormotoma gracilis sublaxa</i> |
| <i>Pianodema subaequata</i> | * <i>Hormotoma latiuscularis</i> |
| <i>Rafinesquina minnesotensis</i> | <i>Liospira micula</i> |
| <i>Strophomena incurvata</i> | <i>Liospira progne</i> |
| <i>Zygospira nicolleti</i> | <i>Lophospira fillmorensis</i> |
| <i>Zygospira recurvirostris</i> | <i>Lophospira obliqua</i> |
| <i>Aristarella nitidula</i> | <i>Lophospira oweni</i> |
| <i>Clionychia lamellosa</i> | <i>Lophospira perangulata</i> |
| * <i>Ctenodonta auburnensis</i> | <i>Lophospira saffordi</i> |
| * <i>Ctenodonta costata</i> | <i>Lophospira spironema</i> |
| <i>Ctenodonta logani</i> | <i>Phragmolites fimbriatus</i> |
| <i>Ctenodonta medialis</i> | <i>Strophostylus textilis</i> |
| <i>Ctenodonta nasuta</i> | <i>Trochonema umbilicatum</i> |
| <i>Ctenodonta oviformis</i> | <i>Pterotheca expansa</i> |
| <i>Cyrtodonta billingsi</i> | <i>Orthoceras sociale</i> |
| <i>Goniophora carinata</i> | <i>Spyroceras bilineatum</i> |
| <i>Modiolodon (?) gibbus</i> | <i>Tripteroceas planoconvexum</i> |
| * <i>Modiolodon subrhomboides</i> | <i>Zitteloceras billingsi</i> |
| * <i>Modiolopsis expansa</i> | <i>Bathyrurus extans</i> |
| * <i>Parallelodus obliquus</i> | <i>Bathyrurus spiniger</i> |
| <i>Whiteavesia subcarinata</i> | <i>Bumastus milleri</i> |
| <i>Archinacella patelliformis</i> | <i>Ceraurus pleurexanthemus</i> |
| <i>Bellerophon capax</i> | <i>Isotelus gigas</i> |
| <i>Bucania halli</i> | <i>Pterygometopus intermedius</i> |
| <i>Carinaropsis acuta</i> | * <i>Pterygometopus lincolnensis</i> |
| <i>Carinaropsis phalera</i> | <i>Leperditia fabulites</i> |
| * <i>Cataschisma typa</i> | * <i>Technophorus bellistriatus</i> |
| <i>Cyrtolites retrorsus fillmorensis</i> | |

17. LOCATION OF THE FOSSIL LOCALITIES IN THE KIMMSWICK OF RALLS AND PIKE COUNTIES, MISSOURI

Frankford; quarried bluff below the level of the railroad, in the eastern part of the town. W. T. Jackson farm; from Frankford $2\frac{1}{2}$ miles north, then about 1 mile east to a bluff north of the spring east of the farm house; in the southern part of section 24 in R 4 W, T 55 N. Henry Hamilton; $3\frac{1}{2}$ miles directly north of Frankford, in the center of section 14, along the road northwest of the house, east of the creek. Big Creek; immediately north of the entrance of Newlon branch, on the W. G. Harvey farm, in the western edge of section 29, in R 5 W, T 56 N. Cave on H. C. Wood farm; from New London 1 mile west and then almost $\frac{1}{2}$ mile north, in the eastern part of section 2.

Sanders branch; in sections 28, 21, and 22, 5 miles northwest of New London. The lowest exposure occurs on the E. E. Priest farm, north of the junction of the two main branches of the creek in section 28, and contains *Dinorthis pectinella*. Northeastward, on the J. H. Luke farm, in the southeastern corner of section 21, *Receptaculites oweni* and *Constellaria varia* are found. These two localities are listed under locality 1 of the accompanying table; the included strata are estimated to have a thickness of 15 feet and to be about 15 feet above the base of the Kimmswick. Locality 2 consists of a thin limestone layer, scarcely $\frac{1}{2}$ foot thick, full of fossils; it is exposed in the southwest corner of section 22, a considerable distance down stream from the cliff spring west of the home of J. W. Briscoe. This locality is estimated as 10 feet above the top of locality 1 and 15 feet below the level of the Briscoe spring. Locality 3 extends from the Briscoe spring to the road crossing east of the home of John H. Kirchner; its total thickness is estimated at 10 feet. Locality 4 extends from the Kirchner road crossing to the first natural rock dam located on the western fork of Sanders branch on the Kirchner farm, and is estimated at 30 feet. Locality 5 is located at an elevation about 20 feet higher, and includes 5 feet of strata on the M. S. Warren farm, in the northwest quarter of section 22, along a bluff exposure containing *Hormotoma major* associ-

ated with some form of *Maclurites*, but *Hormotoma major* is much more common in the immediately overlying strata. The total thickness of strata here involved is 25 feet. The strata in which *Hormotoma major* is abundant are well exposed at locality 6 on the W. Z. Zink farm, in the northeastern part of section 22. The rock here often weathers into coarse grained slabs with tortuous channels on top, and with more or less irregular cavities along the exposed margins. This coarse grained limestone is 15 feet thick, and is overlaid at locality 7 by a fine grained, richly fossiliferous limestone layer, about one foot thick, overlaid by about 9 or 10 feet of similar fine grained rock, but with very few fossils beyond a single siphuncle of *Endoceras* and several specimens of *Streptelasma corniculum*. The Kimmswick limestone is overlaid here by 5 feet of yellowish clay shale of undetermined age.

W. H. Bowles farm; 2 miles west of New London, on south side of road, on east branch of Doe Run, about $\frac{1}{2}$ mile above its confluence with the main creek. Hagan's blacksmith shop; 7 miles west of the Oakwood end of Hannibal, and then 3 miles south, south of road crossing at south end of section 13 in range 6 west. Three-fourths mile east of Shiel, near junction of three forks of main creek, in eastern edge of section 20. One mile northeast of Spalding Springs, at locality reached by going $\frac{1}{2}$ mile northeast from Spalding Springs, and then turning off eastward along a second road, and continuing to the top of the hill land.

Sugar Creek; from Frankford $4\frac{1}{2}$ miles eastward on the pike to Louisiana, to exposures along the southwestern branch of Sugar Creek, south of the pike. McCune; from the railroad station westward to Peno Creek, and then southward along the creek.

18. LOCATION OF FOSSIL LOCALITIES IN THE PLATTIN OF RALLS COUNTY

Henry Hamilton; $3\frac{1}{2}$ miles directly north of Frankford, in center of section 14, northwest of house. Yeager farm; 3 miles northwest of Frankford, on east side of pike to New London, a

short distance northwest of the house. City quarry; about 1 mile southeast of New London on one of the main roads crossing Salt River. Susan Kenney farm; 1 mile north of New London, at the top of the bluff northwest of the bridge crossing a southern tributary of Salt River. Buford Cave; on the M. F. Meyer farm, 2 miles west of New London, and then $\frac{1}{2}$ mile north to a point where the road turns west, near the eastern margin of section 2. J. H. Smith farm; on south side of Salt River, 1 mile northeast of Conn's Ford, near the western edge of section 27, in R 5 W, T 56 N. Conn's Ford; in bed of Salt River, about 4 miles northwest of New London, in northwestern corner of section 33, R 5 W, T 56 N. Big Creek; on the W. G. Harvey farm, about 1 mile northwest of Conn's ford, in the western edge of section 29. Northwest of Spalding springs about 1 mile, at the southern end of section 23 in R 6 W, T 56 N, southwest of the home of H. W. Ogle.

19. UNCONFORMITIES AT TOP OF KIMMSWICK LIMESTONE OF RALLS
AND PIKE COUNTIES

In the central and western parts of Ralls County the so-called Kimmswick limestone is overlaid directly by the Devonian. This includes all localities west and northwest of New London. In the eastern part of Ralls County, however, the Buffalo shales, typically exposed along Buffalo Creek, in Pike County, intervene. An excellent exposure of the Buffalo shales is found in the eastern part of section 29, about 3 miles northeast of New London, and about $1\frac{1}{2}$ miles east of Salt River Switch railroad station. They are well exposed also south of the home of W. H. Benham, on the head waters of the western branch of Peno Creek, about 3 miles south of Frankford, in the southern part of section 15. Here the Buffalo shales are underlaid by coarse grained limestone, 4 feet thick, containing an undescribed species of *Nileus*, (See under section 39 in Description of Species). Another excellent exposure of Buffalo shales occurs 3 miles east of Frankford, on the road to Louisiana. Here a knob formed by the shales contains a large *Rhynchotrema* (See under 11, *Rhyncho-*

trema rowleyi, in Description of Species) and a multiplicate form of *Dinorthis* of the *D. subquadrata* group. Further southward and southeastward in Pike county the Buffalo shales are overlaid by Silurian strata, so that the Devonian limestones rest on successively lower strata on proceeding from southern Pike County north and northwestward across Ralls County. The Buffalo shales correspond approximately to the Maquoketa of Iowa. The immediately overlying part of the Devonian limestone corresponds closely to the Wapsipinicon of the same state.

At the same time those upper parts of the Devonian limestone section which contain *Acervularia* appear confined to the more northwestern exposures of Ralls County, extending in a northeasterly direction from Shiel across the central parts of R 6 W, T 56 N. They correspond to the Cedar Valley limestone of Iowa.

The Edgewood formation of Pike and of the immediately adjacent counties, of Silurian age, apparently was deposited in a restricted basin separated from the Silurian of Iowa by some barrier. During the later Devonian, however, the seas of Pike and Ralls Counties may have been connected with those of Iowa, but a barrier extending across the southern part of Pike and the adjacent parts of Lincoln County may have limited these seas southward, cutting them off from the more southern Devonian areas of Missouri.

20. REMNANTS OF EARLY ORDOVICIAN FAUNAS IN THE EARLY SILURIAN OF MISSOURI

One of the most striking features of the Richmond group is the recurrence of Trenton, Black River, and earlier types, frequently after a long absence during the intermediate Eden and Maysville strata. In the Fernvale member of the Richmond from southern Illinois and in the adjacent part of Missouri, *Hebertella lineolata* Savage belongs to the same generic division as the new species described in this paper from the Kimmswick limestone of southeastern Missouri as *Mcewanella raymondi*. In the Thebes sandstone of southern Illinois, *Conularia delicatula* Savage belongs to a group of species known hitherto only from the Trenton of New York (*Conularia granulata* and *C. papillata*), but in-

cluding also the *Conularia heymani* described in this article from the Plattin limestone of Missouri. The little trilobite *Endymionia bellatula* Savage, described from southern Illinois and north-eastern Missouri, apparently finds its nearest relative in the Canadian *Endymionia meeki* Billings of Quebec and Newfoundland.

In a similar manner the Orchard Creek shale at the base of the Alexandrian (Medinan) of southern Illinois and adjacent Missouri contains such Ordovician elements as *Cyclocystoides*, *Bysso-nychia*, *Lyrodesma*, *Phragmolites*, *Isotelus*, and *Ceratopsis*. The *Calymene dubia* of Savage belongs to the same group as *Calymene christyi* and *Calymene platycephala*, from the Richmond and Trenton respectively, for which the writer recently proposed the generic term *Platycoryphe*.

The association of such Ordovician types with others of Silurian character suggests the proximity of southern Illinois and southeastern Missouri, in early Silurian times, to areas in which Ordovician types still thrived. The associated Silurian forms evidently must have originated as some more distant source, and must have entered the eastern Missouri areas only as migrants.

DESCRIPTION OF SPECIES

1. *Tetradium fibratum* Safford.

Most species of *Tetradium* of Black River age consist of more or less dissociated groups of cells, while massive growths predominate in later strata.

At the top of the Plattin limestone, in Ralls County, a species with more or less flattened massive growth occurs, but in comparatively few numbers. One specimen, found at Conn's Ford, consists of a circular corallum, 32 cm. in diameter, and 6 to 8 cm. thick. Along the exposed surface the corallites are arranged in straight or curved rows which intersect each other at angles varying from 80 to 90 degrees. Usually about 7 corallites occur in a width of 5 mm., varying locally from 6 to 8 in the same distance. The corallites are more or less quadrate in cross-section, single septa extending inward from the middle of each wall, and almost or fully reaching the center of the corallites. Similar specimens occur at the J. H. Smith and Yeager localities.

2. *Beatricea gracilis* Ulrich.

Plate XXIII, fig. 7

Stems 6 to 7 mm. in diameter, and several centimeters long, characterized by the presence of granules connected by the characteristic more or less anastomosing lines as in typical *Beatricea*. Strongly convex septal lamellae occur at intervals and occupy almost the entire width of the stems. In the Auburn limestone at the quarry a short distance north of Auburn, in Lincoln County.

3. *Cornulites flexuosus* Hall.

Specimens closely resembling the type of *Cornulites flexuosus* (Pal. New York, vol. VII, Supplement, 1888, p. 18, pl. 115, fig. 41), from the Trenton of New York, occur on moderately convex forms of *Rafinesquina alternata*, at the top of the Plattin limestone in the city quarry, at the Henry Hamilton locality, and elsewhere in Ralls County. Usually this species is not listed from below the Trenton.

4. *Comarocystites shumardi* Meek and Worthen

Plate XXII, figs. 24 A, B

The type of *Comarocystites shumardi* was described from the Kimmswick limestone at Cape Girardeau, in the southeastern part of Missouri. The specimens here figured came from the top of the Kimmswick limestone exposure at the large quarry about $\frac{1}{2}$ mile northwest of West Kimmswick, in Jefferson County. One specimen consists of a fragment of the theca, bordering on the anal opening, and exposing the interior side. The plates, from this point of view, present a stellate appearance, the rays extending from the center of one plate to the center of one of the immediately adjoining plates. On the sides of the stellate rays the pores open in rows parallel with the crest of the rays. Viewed along the suture planes, between the thecal plates, the pores are elongated vertically and tend to form vertical series. A second figured specimen consists of a single detached plate.

Several additional specimens, consisting of a number of plates still attached to each other, were found at the same horizon.

The *Comarocystites* horizon is regarded as below the Kimmswick strata exposed at the locality south of Thebes, Illinois, which were studied by Prof. T. E. Savage.

Comarocystites punctatus, from the Trenton of the Ottawa area, is remarkable for possessing pinuliferous free arms, with plates arranged in uniserial order (Ottawa Naturalist, 30, 1916, October, November, December numbers.) Uniserial recumbent fixed arms occur in *Amygdalocystites* and *Canadocystis*. Such uniserial arms seem to be characteristic of a restricted closely related group of cystids. At one time, this uniserial arrangement of arm plates was regarded by the writer as primitive. However, it is difficult to maintain this opinion in view of the fact that all early cystids whose arm structure is known have the biserial arrangement. *Gogia prolifica* Walcott (Cambrian Geology and Paleontology, IV, no. 3, 1917, p. 68), from the Lower Cambrian of British Columbia, and *Ecocystites* (?) *longidactylus* Walcott, from the Middle Cambrian of Nevada have biserial arms. This is true also of *Macrocytella mariae* from the Upper Cambrian of Shropshire of England, and *Lichenoides* from the Cambrian of Bohemia.

5. *Clitambonites* cf. *diversus* Shaler

Plate XXIII, fig. 6

Only a single brachial valve of *Clitambonites*, exposing its interior, was exposed in the Kimmswick limestone, in the lower half of the Sanders Creek section, in Ralls County.

An excellent pedicel valve was collected by D. C. Barton from the Kimmswick limestone at the Glencoe Lime and Cement Company quarry, at Mincke, in St. Louis County. In this specimen the cardinal area rises 10 mm. above the hinge-line, the latter being 19 mm. wide, and the maximum width of the valve being 24 mm. The cardinal area forms an angle of about 135 degrees with the plane of contact of the two valves. It is regarded as a new species, but more material will be necessary to differen-

tiate it from the Anticostian Richmond species with which this form usually is identified. Specimen preserved at Harvard University.

Mcewanella nov. gen.

Hebertella lineolata was described by Savage (Illinois Academy of Science, 1917, p. 267, pl. I, figs. 1, 2) from the Fernvale member of the Richmond near Thebes, Illinois, and at Cape Girardeau, Missouri. The same species was described by Eula Davis McEwan as *Platystrophia fernvalensis* (Proc. U. S. Nat. Mus., 56, 1919, p. 428, pl. 50, figs. 1, 2, 3), from the Fernvale limestone at the old quarry southeast of Regenhardt's quarry, northwest of Cape Girardeau, Missouri. This species begins at the beak as a distinctly plicated shell, the plications being distinctly striated longitudinally. Toward the anterior margin the plications become indistinct but the longitudinal striations remain distinct. The median part of the brachial valve is elevated into a fold, and the corresponding part of the pedicel valve is depressed into a sinus.

The anomalous position of this species is indicated by its reference to *Hebertella* by one author, and to *Platystrophia* by a second. By the present writer it is regarded as distinct from both, the sharply defined radial striations being unknown in typical *Platystrophia*, and the distinct plications of the earlier stages of growth being unknown in *Hebertella*. The pedicel valves of both *Hebertella* and *Platystrophia* have deep muscular impressions, those of *Platystrophia* being deeper and narrower. In this respect the species here under consideration resembles *Platystrophia* more closely.

Owing to the occurrence in the Kimmswick limestone of southeastern Missouri of a second species, closely resembling *Hebertella lineolata* generically, the desirability of a separate generic designation for species having this type of structure was increased. Therefore, the name *Mcewanella* is proposed in honor of Miss McEwan, the author of the recent detailed study of the genus *Platystrophia*, cited above.

6. *Mcewanella raymondi* sp. nov.*Plate XXIII, fig. 1*

Only a single brachial valve known, 26 mm. wide at the hinge-line, 20 mm. long, and with a convexity of 9 mm. Valve strongly plicated, the crests of the two median plications being only 3 mm. apart and elevated into a median fold which rises 3 mm. above the bordering depressions. The anterior margin of the shell curves backward 5 mm. along this fold, thus indicating the presence of an equally conspicuous sinus on the pedicel valve. On each side of the median fold of the brachial valve there are five lateral plications, of which the first two are conspicuous, the third is of intermediate size, the fourth and fifth are low, and a distance of about 1.5 mm. intervenes between the fifth plication and the hinge-area. The elevation of the first and second plications is about one millimeter, and their crests are rather abruptly rounded. The entire surface is radiately striated. At a distance of about 5 to 10 mm. back from the anterior margin these striae frequently average about 4 in a width of 2 mm., but nearer the anterior margin, where numerous concentric lines of growth indicate gerontic conditions, the number of these striae may increase to 6 in the same width. The finer details of surface structure are not well preserved.

From the Kimmswick limestone in the Glencoe Lime and Cement Company quarry at Mincke, in St. Louis County, Missouri. Collected by D. C. Barton. Named in honor of Prof. Percy E. Raymond of Harvard University, to whom I am indebted for the loan of this specimen.

7. *Parastrophia hemiplicata* var.*Plate XXI, fig. 4; plate XXII, fig. 4*

Two valves found in the Kimmswick limestone at locality 4 on Sanders branch, in Ralls County, are referred to *Parastrophia* because they present a median septum extending forward as far as midlength of the valve, separating posteriorly into two slowly diverging lamellae such as those forming the narrow spondylium

in *Parastrophia*. There is no indication of sinus or fold, the specimens being small, but along the anterior margin there are traces of short low folds.

8. *Platystrophia shepardi* Castelnau

Plate XXI, fig. 5

Platystrophia shepardi was figured by Castelnau (*Essai Systeme Silurien l'Amerique Septentrionale*, 1843, p. 42, pl. 14, fig. 15) from the magnesian limestone of the Menominee River, near its entrance into Green Bay. According to the Geological Map of Wisconsin, published in 1911, this exposure near Menominee might correspond approximately to the Prosser limestone of Minnesota.

The brachial valve here figured was found at locality 3 in the Sanders branch section, in Ralls County, but it occurs also at similar horizons at other localities in Ralls and Pike Counties.

Most specimens are less elongate along the hinge-line, resembling *Platystrophia trentonensis* McEwan, from the Prosser of Minnesota and Iowa.

9. *Zygospira nicolleti* Winchell and Schuchert

Plate XXIII, fig. 8A, B.

The largest specimen found so far is 4.6 mm. long, 4.3 mm. wide, and has a total depth of 3.2 mm., the pedicel valve being slightly more convex than the brachial one. The median part of the pedicel valve is angularly arched, and from this median part the sides slope strongly downward toward the lateral margins. The general surface of the brachial valve is convex; anteriorly the median part is depressed into a sinus. Found near the top of the Plattin limestone at the Buford Cave, at the Yeager locality, and elsewhere in Ralls County, Missouri.

This species is related generally to *Zygospira*. Externally it resembles *Protozeuga anticostiensis* Twenhofel, from the Richmond of Anticosti, in the broad anterior median sinus on the brachial valve and in the keeled median convexity of the pedicel

valve. In one specimen there is a slight tendency toward the elevation of the anterior sulcus of the brachial valve along its median line, and from this it is assumed that the anterior part of the median elevation of the pedicel valve might be slightly depressed along its median line, but neither tendency finds sufficient expression in any of the specimens at hand to admit of positive observation. *Protozeuga sulcocarinata* Savage, from the Alexandrian (Medinan) of Illinois and Missouri, appears closely related to the Anticosti form. The Plattin species, here under consideration, is supposed to be identical with the Black River species *Zygospira nicolleti*, which was described originally under *Hallina*.

10. *Rafinesquina deltoidea* Conrad

Plate XXI, figs. 2, 3; plate XXII, figs. 2, 3.

The small specimens of *Rafinesquina*, here identified as *Rafinesquina deltoidea* (fig. 3), are not distinctly deltoid in form, but they correspond most nearly to the specimen figured by Hall and Clarke under that name (Pal. New York, 8, pt. 1, 1892, pl. 9A, figs. 1, 2), from the Trenton at Jacksonburg, New York. Most of these specimens do not exceed 20 mm. in length, but are so strongly convex as to indicate their full maturity. Abundant at localities 3 and 4 in the Kimmswick limestone of the Sanders Creek section.

A single valve (fig. 2), from locality 4 of the same section, resembles the specimen figured by Hall as *Leptaena* (= *Rafinesquina*) *deltoidea* (Pal. New York, 1, 1847, pl. 31 A, fig. 3a), from the Trenton limestone at Trenton Falls, New York. It is 28 mm. long, 27 mm. wide, and has a convexity of 9 mm.

Larger, and relatively less convex shells, such as those usually identified as *Rafinesquina alternata* (Emmons), also occur at locality 3 on Sanders branch. One specimen is 31 mm. long, 35 mm. wide, and has a convexity of 7 mm.; in other specimens the convexity is even less.

All specimens of *Rafinesquina alternata* from the Plattin limestone of Ralls County are only moderately convex, the convexity usually not exceeding 4 mm.

11. *Rhynchotrema rowleyi* sp. nov.*Plate XXIII, fig. 2 A-D*

Shells of large size, occurring as separated valves with the anterior margin more or less broken off. In the three best preserved pedicel valves, with lateral diameters of 28, 29, and 33 mm., the lengths are estimated at 27, 29, and 33 mm., and the convexities at 8, 8, and 9.5 mm. respectively. Three plications occupy the sinus of the pedicel valve, and five or six plications occupy each side, leaving an unplicated space 5 or 6 mm. wide between the last plication and the postero-lateral angle of the valve. Four plications occupy the median fold of the brachial valve, and four occur on each side, occasionally with a trace of a fifth lateral plication. The plications are crossed at regular intervals by conspicuous and rather coarse concentric striae, of which five or six occur in a length of 5 mm. on the more central parts of the valves and toward the beak. In addition to the coarser striae, some valves show much finer concentric striae, and the latter tend to dominate along the unplicated postero-lateral parts of the valves and also along the anterior, more or less gerontic part of the valves.

The interior of both valves is constructed as in *Rhynchotrema capax*, but the muscle scars are more deeply impressed. Adductor scars impressed in the posterior part of the muscular area, distinctly defined laterally, 3 mm. wide and almost 6mm. long. The remainder of the muscular area is occupied by the diductor scars which are crossed by more or less irregular radiating lines. The posterior part of the diductor scars embraces the adductor scars. The area occupied by the diductor scars is deeply impressed postero-laterally and is fairly distinct even anteriorly; its width is 11 mm., and its length is 12 or 13 mm. The pitted ovarian markings occupy the area between the deeply impressed postero-lateral parts of the diductor scars and the nearest lateral margins of the shell. The teeth project upward and inward, and posterior to the teeth are distinct sockets for articulation with the posterior part of the hinge plates on the brachial valve.

The cardinal process in the brachial valve consists of a very narrow median vertical plate, on each side of which are the bases supporting the crura. The crura project forward from near the inner margins of these bases, and the surface of the latter tends to be distinctly concave toward the cardinal process. The posterior part of the bases articulates with the sockets posterior to the teeth of the pedicel valve, and sockets for the reception of these teeth occur exterior to the bases supporting the crura in the brachial valve. The cardinal process and the adjacent parts of the bases unite anteriorly and connect with the median ridge which extends slightly more than half the length of the valve forward. About 4 or 5 mm. in front of the cardinal process there are more or less distinct lateral branches of the ridge, evidently limiting the anterior from the posterior adductor scars.

From the Buffalo or Maquoketa shales 3 miles east of Frankford, in Pike County, at a small knob on the north side of the pike to Louisiana. Named in honor of Prof. R. R. Rowley of Louisiana, who for many years has investigated the strata of eastern Missouri. Characterized by its large size and by the conspicuous and distant concentric striae.

12. *Schizocrania filosa* Hall

In the eastern part of the United States the earliest occurrence of this species is in the Trenton. In Minnesota it occurs as low as the Decorah shales. In Ralls County, Missouri, it is fairly common at several localities near the top of the Plattin limestone; among others, at Conn's Ford, Buford Cave, and along the lower part of Big Creek.

13. *Strophomena* cf. *incurvata* Shepard

Plate XXI, fig. 1, plate XXII, fig. 1

A single specimen of *Strophomena*, 56 mm. wide along the hinge-line, and 34 mm. long from the beak of the pedicel valve to its margin, was found at locality 3 on Sanders branch, in Ralls County, in the Kimmswick limestone. The concavity of the

pedicel valve is moderate, scarcely exceeding 2 mm.; the convexity of the brachial valve may not have exceeded 7 mm., as far as may be judged from the part remaining. The hinge-area of the pedicel valve is relatively high, equalling at least 3 mm. at the beak. The angle between this cardinal area and the general surface of the pedicel valve is about 15 degrees. The posterolateral angles equal about 70 degrees. The surface of the valves is covered with radiating striae, 6 or 7 in a width of 2 mm. Every fourth one of these striae tends to be slightly more prominent, this tendency being greater in the brachial valve. The individual specimen here described is associated with numerous specimens of typical *Strophomena incurvata*, and may be only an aberrant form of the latter.

14. *Trematis huronensis* Billings

Outline circular, upper valve moderately convex, the convexity increasing toward the beak. Largest specimen found is 25 mm. in width and 22 mm. long. The surface is ornamented by radiating and concentric striae, the intercepted areas being occupied by small elliptical or more or less quadrangular pits. In some specimens the striae and pits are distinctly perceptible as far as the beak. In these specimens, both the radiating and the concentric striae tend to be narrow, and the intercepted pits tend to be more quadrangular. In other specimens the pits diminish more rapidly in size than the intermediate striae toward the beak, finally appearing as minute circular pits arranged in rows on an area which otherwise is smooth; sometimes the pits disappear altogether before reaching the beak. In a third group of specimens, the concentric striae are considerably narrower than the radiating ones, at least posteriorly, and especially between 5 and 10 mm. from the beak. Anteriorly, in the more mature stages of growth, the specimens are much alike; both the radiating and concentric striae are narrow and the intercepted pits are more or less quadrangular. In the mature stages of growth the number of pits usually varies from 8 to 9 in a width of 2 mm., but in the final stages of growth this number may in-

crease to 10 or 11 in the same distance. Occasional specimens occur in which the number of pits at midlength of the shell, just before reaching the point of intercalation of additional rows of pits, may equal 7, or even 6 in a width of 2 mm. On closer examination, the concentric striae are found to be not strictly continuous. From 4 to 10 pits may form a continuous series in a lateral direction; then there is a slight jog, beyond which there is another continuous series of pits. Only a single specimen was found in which the pits of adjacent concentric rows alternated sufficiently to accord with the description and figure of *Trematis ottawaensis* Billings (Palaeozoic Fossils, 1865, p. 53, fig. 58), from the Trenton limestone at Ottawa, Canada.

The specimens here described occur in the top of the Platin limestone at Conn's Ford, Buford Cave, and at the Yeager locality.

In *Trematis punctostriata* Hall, from the type horizon and locality, in the Saltillo (Trenton) limestone at Clifton, Tennessee, similar features are shown. Posteriorly the pits are small and distant, on an otherwise smooth surface, disappearing before reaching the beak. Anteriorly the pits are separated only by narrow radiating and concentric striae. The number of pits sometimes reaches 8 in a width of 2 mm. near midlength of the shell, increasing to 10 and 12 in the same width along the anterior margin. The concentric arrangement of pits is continuous for distances including 4 to 10 pits, beyond which there is a slight jog, followed by another continuous series of pits. Alternation of pits belonging to adjacent rows, as described in *Trematis ottawaensis*, is confined to only three or four rows in those few cases where it was detected at all.

15. *Zygospira deflecta* Hall

Plate XXII, figs. 5 A, B

Shells small, scarcely exceeding 3 mm. in length, characterized by a broad and distinct median depression on the brachial valve, its entire width occupied by five radiating plications, the total number of plications on the valve usually equalling 17 to

21. The median part of the pedicel valve, for a width of 4 radiating plications, is distinctly elevated above the rest of the valve. Contrasted with the brachial valve, the pedicel valve is considerably more convex.

Found at the top of the Platin limestone, at Buford Cave, and at the Yeager locality, in Ralls County.

The specimens here described agree fairly well with those figured by Hall (plate XXII, figs. 5 A, B of this bulletin), from the middle Trenton at Martinsburg, New York, as *Atrypa* (= *Zygospira*) *deflecta*. *Zygospira recurvirostris* (Hall), from the same locality and horizon, differs from *Zygospira deflecta* chiefly in the greater convexity of the brachial valve and in the much less conspicuous depression of the median part of this valve. If it be possible to separate *Zygospira recurvirostris* from *Zygospira deflecta* by means of these characteristics, then the Platin limestone specimens come nearer to *Zygospira deflecta*. If these two species prove not distinct, then both must bear the name *Zygospira deflecta*, since the original description of *Zygospira deflecta* precedes that of *Zygospira recurvirostris* in the original description of these species (Paleontology of New York, 1, 1847, p. 140, pl. 33, figs. 4 a, b).

16. *Ctenodonta* of gibberula group.

Plate XXI, fig. 13

A single left valve of some species of *Ctenodonta* was found near the top of the Platin limestone, about 1 mile northwest of Spalding Springs, near the home of H. W. Ogle. Compared with *Ctenodonta gibberula* Salter (plate II, fig. 13 of this bulletin), the shell is of smaller height, the ventral margin is much less convex, the angle between the hinge areas anterior and posterior to the beak is more divergent, and the entire aspect of the shell is more elongate.

17. *Parallelodus obliqua* Branson*Plate XXI, fig. 14*

A distinct and rather angular umbonal ridge extends from the beak toward the lower posterior angle. The post-umbonal slope is distinctly concave, especially toward the beak. The remainder of the valves, below and anterior to the umbonal ridge, is gently and evenly convex. There is no trace of a mesial depression or sinus. The ventral margin is gently and evenly convex for almost its entire length, rounding more abruptly upward at the two extremities of the shell. The posterior margin of the shell is strongly oblique to the hinge-line, producing a rather narrowly rounded posterior angle. None of the specimens expose the teeth. The general appearance is that of *Modiolopsis*, but the absence of a mesial depression suggests the possibility of identity with *Parallelodus*.

In *Modiolopsis consimilis* Ulrich (plate II, fig. 14, of this bulletin), the ventral margin is nearly straight and the slope between this margin and the umbonal ridge is distinctly flattened.

18. *Cyrtolites ornatus minor* Ulrich and Scofield

Two forms of *Cyrtolites* occur near the top of the Plattin limestone in Ralls County. The largest specimens reach a diameter of fully 18 mm. Those specimens in which the transverse undulations meet the carina almost at a right angle are referred to *Cyrtolites ornatus minor*, while those in which the undulations curve strongly backward are regarded as a variety of *Cyrtolites retrorsus* Ulrich.

19. *Holopea* cf. *concinnula* Ulrich and Scofield*Plate XXI, fig. 7*

A specimen found at the top of the Plattin limestone at Conn's Ford has about the same apical angle as typical *Holopea concinnula* (plate XXII, fig. 7 of this bulletin), but the shell is smaller and the rate of enlargement of the volutions is less rapid.

20. *Holopea* cf. *parvula* Ulrich*Plate XXI, fig. 6*

A specimen of *Holopea*, 24 mm. in diameter, was found at the top of the Plattin limestone at Conn's Ford. In the elevation of its spire and in the rate of enlargement of its last volution, this specimen resembles the much smaller species *Holopea parvula* (plate XXII, fig. 7, of this bulletin), from the Flanagan member of the Trenton of central Kentucky.

21. *Hormotoma gracilis angustata* Hall*Plate XXI, fig. 8*

A species of *Hormotoma* is very abundant at every locality in Ralls County, where the top of the Plattin limestone is exposed. The specimens attain a larger size than those ordinarily referred to *Hormotoma gracilis angustata*. Compared with *Hormotoma gracilis sublaeta*, from the Auburn of Lincoln County, the volutions are less oblique.

22. *Hormotoma* (?) *major* Hall

This species is quite common in the coarsely granular or crystalline McCune limestone in Pike County; if the name McCune be restricted to strata equivalent to the exposures found near McCune station, then the species may be said to characterize this division of the Kimmswick, using the latter term in the broad sense employed by Branson. One of the Pike County specimens was figured by Ulrich in the *Paleontology of Minnesota*, vol. III, pt. 2, 1897, on plate 71 (figs. 5, 6).

23. *Maclurina manitobensis* Whiteaves

A single specimen, 50 mm. wide, from the lower part of the *Hormotoma major* or McCune zone, was found on Sanders branch, in Ralls County. It is referred to *Maclurina* on account of the small width of the umbilicus. While the shell is considerably

smaller than mature specimens of *Maclurina manitobensis*, the umbilicus apparently enlarged at the same rate and the keel surrounding this umbilicus rises at about the same angle. In *Maclurina cuneata* the keel rises much more rapidly, and the umbilicus is much narrower.

24. *Maclurites* sp.

A single specimen, 50 mm. wide, from the *Hormotoma major* zone on Sanders branch, is referred to *Maclurites* on account of the relatively wide umbilicus. The specimen may be regarded as a depressed form of *Maclurites bigsbyi* Hall, a Platteville species found in Wisconsin and Minnesota, the shell being more depressed even than figure 7 on plate 75 of the Paleontology of Minnesota, III, part 2, 1897; moreover, the peripheral angle is more acute and the umbilicus exposes fewer volutions. Compared with *Maclurites depressus* Ulrich, from the Platteville of Minnesota, the width of the umbilicus is similar, and the peripheral angle is only moderately greater, but there is no tendency toward concavity on the flattened side of the volutions. Compared with *Maclurites crassa*, Ulrich and Scofield, and its variety *macra*, the umbilicus is much smaller, and the peripheral angle is more acutely rounded.

25. *Conularia heymani* sp. nov.

Plate XXI, fig. 12, plate XXII, fig. 12

Only one of the four faces of the shell is exposed and even of this face the lateral margins are not distinctly defined. As far as may be determined from the part exposed, the lateral margins of the one face here described diverge at an angle of about 15 degrees. The median line of the face is occupied by a narrow groove, on each side of which is a slightly raised line, light brown in color. At the smaller end of the specimen the raised lines are about 0.8 mm. apart; 20 mm. farther up they are about 1.25 mm. apart. Beyond this point they can not be measured accurately. The face is crossed transversely by very fine striae which

rise from the lateral margins as far as the slightly raised lines on each side of the median groove, forming an angle of about 75 degrees with these raised lines. Between these lines the transverse lines curve so as to cross the median groove without any interruption or abrupt change of direction.

The number of transverse striae varies from 6 to 9 in a length of 1 mm. near the smaller end of the specimen and also farther up, at midlength. At the larger end, where gerontic conditions appear to have set in, the number of these transverse striae equals 11 to 12 in 1 mm. The transverse striae are very narrow, and their crests are lined with minute granules, numbering from 11 to 17 in a distance of 1 mm. on various parts of the shell. The granules are arranged also in vertical rows. The linear areas between the transverse striae are depressed into broad and rather shallow grooves. Along that margin of the grooves which is nearer the apical end of the shell, very low granules appear, but these granules alternate in position with those on the transverse striae and are visible only under a lens.

The transverse striae cross the pair of slightly raised vertical lines along the median part of the face, as though these lines did not exist. The raised lines appear to be due to features not on the exterior but on the interior of the shell. Along the raised lines the interior of the shell appears to be thickened. In a fossil state this thickened part tends to be preserved better than the adjacent parts. Moreover, during fossilization it tends to be lifted slightly above the adjacent parts. The median groove appears to locate a line of weakness in the shell. In cross-sections the raised lines are seen to be due to the presence of a pair of very short longitudinal septa on the median part of the inner side of each face of the shell.

Found at the top of the Platin limestone at Conn's Ford, four miles northwest of New London, in Ralls County. Named in honor of A. W. Heyman, in memory of many days spent on geological trips in Ohio and Missouri.

Conularia heymani differs from *Conularia granulata* Hall (Pal. New York, 1, 1847, p. 223, pl. 59, figs. 5 a, b), from the Trenton at Middletown, New York, in the absence of distinct vertical striae connecting the vertical rows of granules.

26. *Conularia* sp.

Plate XXI, fig. 9; plate XXII, fig. 9 A, B

Half a dozen fragments of some very thin-shelled *Conularia*, rolled up into a more or less tubular form, were found within the living chamber of some Orthoceroid shell. The fragments are enrolled laterally. This is indicated by a narrow dark brown line extending lengthwise down the enrolled fragments. The width of this line is approximately $\frac{1}{4}$ mm. Along this line the inner side of the shell is supported by a narrow sharp septal ridge, extending about $\frac{1}{8}$ mm. from the wall of the shell inward. This septal ridge is colored deep brown, and it is the color of this ridge which is seen through the thin wall of the shell itself and which forms the narrow dark brown line as seen on the exterior of the shell. Possibly a minute tube may have run down the interior of this septal ridge, close to the wall of the shell, but this could not be determined beyond all doubt. In order to conform with *Conularia* of the *C. heymani* type, a second brownish line ought to extend down the tubular fragments, parallel to the brownish line actually found, but in none of the fragments was a second line found. However, since in no case a sufficient width of surface was exposed on both sides of the brownish line actually present, it is not possible to determine definitely either the presence or absence of such a second parallel brownish line. Judging from analogy with *Conularia heymani*, it is here assumed that the second brownish line should occur in specimens showing a sufficient width of the original shell wall.

The longest enrolled fragment is 26 mm. long, and the various fragments are enrolled so as to produce the appearance of tubes about 4 or 5 mm. in diameter. All of the so-called tubes are more or less crushed and have their enrolled margins more or less separated.

The surface is ornamented by minute granules, about a 0.05 mm. in diameter. These granules are arranged both in transverse and in vertical rows. In the transverse rows 10 to 13 granules occupy a width of one millimeter, and in the vertical rows usually about 8 granules occupy the same length, although

their number varies from 7 to 9, and 11 occasionally are found. The transverse rows of granules tend to be supported by low transverse wrinkles or striae, but the intermediate grooves never are sharply defined and the wrinkles or striae often are obsolete. In the latter case the granules appear arranged in rectangularly intersecting rows on otherwise nearly smooth surfaces. On some fragments, numerous low parallel wrinkles more or less connect the granules in a diagonal, not in a vertical, direction, somewhat as in *Conularia cayuga* as figured by Hall (Pal. New York, 5, pt. 2, 1879, pl. 34, fig. 5) from the Hamilton group of New York.

From the city quarry, one mile southeast of New London, in the upper part of the Platin limestone.

27. *Hyalithes baconi* Whitfield

Plate XXI, figs. 10 A, B, 11; plate XXII, figs. 10, 11

Apical angle 20 degrees. Top of shell 9 mm. in width. Cross-section somewhat triangular, with one side flattened and the opposite side convex, the dorso-ventral diameter at the top of the shell being 2.5 mm. in the shell here described. The small size of this diameter may be due in part to compression. The shell is striated transversely, the direction of these striae being almost directly transverse on the convex side of the shell, while on the flattened side they curve distinctly upward.

In one specimen (fig. 11) the median part of the convex side is slightly more convex than the lateral parts of this side, and is separated from the latter on each side by a slightly concave area. The lateral margins are narrowly rounded. Of the transverse striae 14 occupy a length of 3 mm. at the larger end of the shell, preceded by 15 in the same distance at midlength, increasing still farther in number toward the apical end. The transverse striae are crossed by much finer vertical striae, of which 8 to 10 occur in a width of 1 mm.

Hyalithes baconi is fairly common at one horizon near the top of the Platin limestone, but most specimens do not show the low median elevation on the convex side of the shell and the fine

vertical striae rarely are shown. Possibly most specimens lacking these vertical striae are casts of the interior of the shell.

Found at Buford Cave, 2 miles west of New London, near the top of the Plattin limestone.

28. *Hyolithes miseneri* Foerste

Under the name *Conularia miseneri* the writer described a series of specimens from the Whitewater member of the Richmond at Richmond, Indiana (Journal of Cincinnati Soc. Nat. Hist., 22, 1917, p. 42, pl. I, figs. 1 A, B, C). Later it was recognized that the supposed *Conularia* was the convex side of a species of *Hyolithes*, the median part of which was elevated as in the second specimen of *Hyolithes baconi*, described in the preceding lines. The transverse striae are more prominent. Along the median line of the shell they curve slightly downward; laterally they curve more strongly downward as far as the lateral sides of the shell where they begin to curve rapidly upward. From this it is assumed that on the flattened side of the shell the transverse striae curve strongly upward as in other species of *Hyolithes*. The vertical striae are finer but distinct. An almost identical species occurs in the Kimmswick of southern Missouri.

29. *Orthoceras* with vertical color bands.

In a specimen of an unknown species of *Orthoceras* found at the top of the Plattin limestone at Conn's Ford, vertical color banding is present. The specimen is 22 mm. in width. The color bands equal or slightly exceed 1 mm. in width and are 1 mm. or slightly less apart. The color banding is a feature characteristic of the inner layers of the shell and is seen best where the surface of the shell has weathered away.

Orthoceroid shells with vertical color bands are known also at other horizons. In the Lorraine formation in the river bed west of Weston, Ontario, vertical color bands occur in an Orthoceroid shell 22 mm. wide, having a siphuncle with nearly spherical segments (*Loxoceras*?). About 8 vertical color bands occur in a width of 5 mm., the width of the color bands and that of the intervals between being about the same.

In a similar species (*Loxoceras* ?), from the Richmond formation at the Clay Cliffs on the eastern shore of Manitoulin Island, the vertical color bands are about 1 mm. in width and are separated by intervals varying from 1 to 2 mm. where the diameter of the shell equals 15 mm.

In *Orthoceras trusitum* Clarke and Ruedemann, from the Guelph at Rochester, New York, specimens occasionally show color banding. In the specimen represented by figure 2 on plate 13 of Memoir 5, New York State Museum, 1903, there are 9 or 10 vertical light brown bands in a width of 3 mm. In the specimen represented by figure 9 the structure usually accompanying color banding is present, but there is no distinctive color here. This structure consists in the space between the color bands being composed of a less dense and more readily weathering material than that forming the color bands.

In all cases of color banding observed by the writer the color banding consisted of various tints of brown.

30. *Spyroceras bilineatum* Hall

In typical *Spyroceras bilineatum*, from the Trenton of New York, the coarser vertical striae alternate with finer ones. Conchs of this type occur at the top of the Platin limestone at Conn's Ford, Buford Cave, and elsewhere in Ralls County. They are accompanied by other specimens in which the vertical striae practically are of uniform size. In one specimen 17 mm. in diameter, these vertical striae number 12 or 13 in a width of 5 mm.

31. *Tripterocheras* cf. *planoconvexum* Hall

In the *Hormotoma major* zone $4\frac{1}{2}$ miles east of Frankford, in Pike County, south of the crossing of the pike to Louisiana across the western branch of Sugar Creek, a species of *Tripterocheras* was found which is identical with the species figured by Clarke from the Prosser limestone at Hader, Minnesota (Pal. Minnesota, III, pt. 2, 1897, pl. 57, fig. 1). Compared with typical *Tripterocheras planoconvexum*, from the vicinity of Beloit, Wisconsin, however, the species here under consideration appears larger, and with a smaller apical angle.

32. *Amphilichas cucullus* Meek and Worthen

This species was described from the Kimmswick limestone in Alexander County, Illinois, presumably from the exposure south of Thebes studied by Professor Savage. The same species is common in the second quarter of the so-called Kimmswick limestone of Ralls and Pike Counties, measuring upward from the base. It is one of the most characteristic fossils of this horizon. It is overlaid by the *Hormotoma major* or McCune zone.

33. *Bumastus holei* sp. nov.

Plate XXI, figs. 15 A, B; plate XXII, figs. 15 A, B

The cast of the lower side of the cranium is characterized by shallow impressed lunettes, relatively very distant from each other, but rather close to the posterior margin. The length of the cranium is 25 mm.; its width is 30 mm.; the distance between the impressed lunettes is 18 mm.; the length of the lunettes is 5 mm., and their posterior margin is 5 mm. from the posterior margin of the cranium. The general convexity of the cranium from side to side is small.

The associated pygidium is 28 mm. wide, 19 mm. long, and has a convexity corresponding to that of the cranium. The articulating axial part is 11 or 12 mm. in width, and from this axial part the lateral articulating margins bend back at an angle of about 155 degrees.

Found at locality 3 in the Kimmswick limestone section on Sanders branch. Probably identical with the species figured by Clarke (Pal. Minnesota, III, pt. 2, 1897, p. 722, fig. 36) as *Bumastus orbicaudatus* from the Prosser of Minnesota. The posterior part of the cranium is not preserved well enough to determine whether or not a median pustule was present here originally named in honor of Prof. A. D. Hole, of Earlham College, Richmond, Indiana.

34. *Bumastus rowleyi* sp. nov.

Plate XXI, figs. 16 A, B; plate XXII, figs. 16 A, B

Cranidium 19 mm. long, 21 mm. wide between the palpebral lobes, and 22 mm. wide at the broadest part anterior to the palpebral lobes. The general aspect of the cranidium resembles that of *Bumastus ambiguus* Foerste from the Brassfield limestone of Ohio and Indiana. The cast of the lower side of the cranidium shows impressed lunettes along the dorsal groove. These lunettes are separated by a distance of nearly 10 mm. from each other. They are 3 mm. long and are 4 mm. distant from the posterior margin of the cranidium. Both anterior and posterior to the lunettes the dorsal grooves curve strongly outward. Anterior to the lunettes the dorsal grooves are very faint and terminate in distinct pits at points 15.5 mm. from each other and 11 mm. from the posterior margin of the cranidium. Each pit contains a small central granule. The cranidium is moderately convex except toward the anterior margin where it curves rather abruptly downward.

The associated pygidium is 22 mm. long, 27 mm. wide, and has an anterior elevation of 7 mm. The cast of the lower surface is moderately concave along the doublure, but the upper surface appears to have been slightly convex from the more convex middle parts of the pygidium as far as the posterior margin.

Found at locality 3 in the Kimmswick limestone section along Sanders branch in Ralls County. Compared with *Bumastus indeterminatus* Walcott, from the Leray-Black River of New York (Bull. Mus. Comparative Zoology, 60, 1916, pl. 2), *Bumastus rowleyi* has a longer, narrower cranidium with a different curvature along the anterior part of the dorsal grooves on the cranidium, and the general outline of the pygidium is more triangular, especially posteriorly.

35. *Ceraurinus* cf. *trentonensis* Barton

Glabella expanding anteriorly; in one cranium 12 mm. long, the width of the glabella increases from 8 to almost 10 mm. from the rear toward the front. The general form of the glabella is depressed convex, and is distinctly limited laterally by the relatively shallow dorsal furrow. The first and second pairs of glabellar furrows are distinctly curved; from the dorsal furrow they curve gently forward and then, for a longer distance, backward, the inner ends terminating farther back than their outer ends. The third or posterior pair of glabellar furrows is directed diagonally backward, at an angle of about 55 degrees with the median line of the glabella, joining the occipital furrow at points only 2 mm. distant from each other. The posterior pair of glabellar lobes is distinctly triangular. The first and second pairs of glabellar furrows are narrow and sharply incised. The surface of the glabella is almost smooth or minutely granulated. On the fixed cheeks minute pits may be detected. In general appearance, these crania resemble those of *Cheirurus* in which the posterior pair of glabellar furrows is strongly defined as far as its connection with the occipital furrow (Ohio Jour. Sci., 19, 1919, p. 396, pl. 19, fig. 7).

Found at locality 4 on Sanders branch, in the Kimmswick limestone.

In general aspect this species resembles *Ceraurinus scofieldi* (Clarke) from the Platteville at Minneapolis, Minnesota (plate XXII, fig. 19, of this bulletin), but the first and second pairs of glabellar furrows in that species are less distinct and less curved.

36. *Ceraurus* cf. *bispinosus* Raymond and Barton

Plate XXI, figs. 18 A, B, C

The dorsal furrows limiting the sides of the glabella diverge at angles between 22 and 27 degrees in different specimens. All of the glabellar furrows are strongly indented. The eyes are nearly opposite the second pair of glabellar furrows or slightly farther forward. They are about equally distant from the

dorsal furrow and from the furrow following the posterior outline of the fixed cheeks. The ocular ridge is either faint or obsolete; when present, it starts off from the vicinity of the first pair of glabellar furrows. The pustules tend to be more conspicuous anteriorly and also along two diverging lines which extend from near the neck furrow forward toward the frontal lobe in such a manner as to leave a median area in which the pustules are less prominent. The pustules are less prominent also between the two rows of more prominent pustules and the lateral glabellar lobes. On the largest cranium, 14 mm. long, the most prominent pustules attain a height of 0.5 mm. None are developed into spines. The fixed cheeks are indented with pits, and between these there are a few granules of which several tend to be prominent.

Found at locality 2 along Sanders branch, in the Kimmswick limestone.

From typical *Ceraurus bispinosus* Raymond and Barton (plate II, fig. 23 of this Bulletin), from the Black River formation of the Ottawa area in Canada, the Ralls County specimens differ chiefly in the absence of any pustules sufficiently strong to suggest the presence of spines. From *Ceraurus dentatus* Raymond and Barton, from the Trenton formation of Ontario and New York, they differ in having more rotund glabellar lobes.

37. *Ceraurus plattinensis* sp. nov.

Plate XXI, figs. 18 A, B; plate XXIII, figs. 3 A, B

Cephalon relatively short. The continuation of the occipital furrow along the posterior part of the fixed cheeks is nearly straight as far as the genal angle; in consequence the angle between the posterior margin of the cephalon and the genal spines appears more abrupt. In other respects the backward curvature of the genal spines resembles that of *Ceraurus dentatus*. The lateral lobes of the glabella are small and rotund, while those of *Ceraurus dentatus* are more nearly transversely oblong. The eyes are set far back, almost opposite the second pair of lateral lobes or slightly farther forward. A faint ocular

ridge passes from the anterior pair of glabellar furrows obliquely backward to the palpebral lobe, or may be entirely absent. The axial lobe of the thorax is relatively broader and the free terminations of the pleural segments spread out farther than in *Ceraurus dentatus*. The strongly developed spines of the pygidium not only curve strongly backward but are even slightly convergent posteriorly. That part of the pygidium which is included between these spines resembles the pygidium of *Ceraurus pleurexanthemus*; no dentate margin is present as in *Ceraurus dentatus*.

From the top of the Platin limestone at the city quarry a mile southeast of New London, along the lower part of Big Creek, at the Buford Cave, and elsewhere in Ralls County.

38. *Endymionia bellatula* Savage

This species was described by Savage (Illinois Acad. Sci., 1917, p. 273, pl. I, fig. 3) from the Thebes sandstone, near Thebes, Illinois. It is cited by him also from Madison Creek, in Calhoun County, Illinois, and from Dover church, in Pike County, Missouri. Prof. R. R. Rowley discovered long ago a locality on the Goodman place, $\frac{1}{2}$ mile west of Calumet post-office, where this little trilobite occurs in great abundance about 3 or 4 feet above the base of the Buffalo shales.

39. *Nileus* sp.

Plate XXIII, fig. 4 A, B

Eyes very prominent, attaining an elevation of 2.5 mm. in cranidia 15 mm. long, rising rather abruptly above the general surface of the cephalon, and limited on the inner side by broad though shallow depressions. In specimens whose palpebral lobes are 10 mm. apart the shallow depressions along their inner sides have their deepest parts about 6 mm. apart. The median parts of the cranidia, between these shallow depressions, may be regarded as the poorly defined glabella which broadens anteriorly and merges into the general curvature of the cranidium.

Posteriorly a few specimens show traces of a prolongation of the shallow depressions backward in the form of almost obsolete dorsal furrows. The anterior part of the cranium curves downward without any indication of a marginal concave curvature of the cephalon. Anteriorly the facial sutures meet at an obtuse angle; nevertheless this angle is sufficient to indicate that the facial sutures could not have been practically marginal.

Pygidium convex as far as the posterior margin. Axial lobe almost or entirely obsolete. Antero-lateral margins curved abruptly downward along a distinctly angular ridge. Between this ridge and the antero-lateral angle, the slope is distinctly concave. Posteriorly, the margin of the pygidium is slightly angular rather than evenly convex.

From the limestone immediately beneath the Buffalo or Maquoketa shales at the W. H. Benham locality, 3 miles south of Frankford, in Pike County. This limestone rests on the top of the typical Kimmswick, and is regarded as also of Mohawkian age.

Compared with *Nileus vigilans* Meek and Worthen, from the lower Maquoketa of the upper Mississippi valley, the Trenton form here described, according to E. O. Ulrich (in a letter), has much less prominent eyes, larger palpebral lobes; the eyes situated farther from the anterior edge of the cephalon; the anterior outline of the cephalon is more uniformly rounded; the fixed cheeks are shorter; the front slope of the cranium is less sharply deflected; the antero-lateral angles of the cranium are less rounded; and the corresponding parts of the free cheeks, where they bend around the front of the cranium, are narrower.

40. *Proetus undulostriatus* Hall.

A small cranium, 3 mm. in length, was found at locality 2 along Sanders Creek, in Ralls County. It differs from typical *Proetus undulostriatus* from the Trenton (Snake Hill) of New York, chiefly in the greater distance between the anterior margin of the glabella and the narrow anterior border of the cephalon. Moreover, the intervening part is distinctly convex, and at the

line of contact with the glabella it is distinctly indented. In these particulars the Ralls County specimen agrees better with the minute specimen of *Proetus* figured by Ruedemann (Bull. New York St. Mus., No. 49, 1901, p. 62, pl. 4, figs. 5, 6, 7), from the Trenton (Rysedorph) of New York.

41. *Pterygomietopus* cf. *lincolnensis* Branson

Plate XXI, fig. 19

Pterygomietopus lincolnensis Branson differs from *Pterygomietopus eboraceus* (plate II, fig. 20, of this Bulletin), from the Trenton of New York, in the absence of genal spines; the third pair of lateral glabellar lobes is not confluent with the second; no tubercle occurs on the occipital ring; the frontal lobe of the glabella is shorter and broader; the eyes are larger; and the fixed cheeks are smaller. At the top of the Plattin limestone, at the Buford Cave, specimens resembling *Pterygomietopus lincolnensis* occur, but these have distinct genal spines. An examination of the types of Branson's species suggests that better preserved specimens of the latter may also have genal spines.

Another form similar to *Pterygomietopus lincolnensis*, found in the Tyrone member of the Black River formation at High Bridge, in central Kentucky, was described by me recently as *Pterygomietopus confluens* Foerste (Ohio Jour. Sci., 19, 1919, p. 396, pl. 19, fig. 19). It is refigured in this bulletin as figure 22 on plate II. It differs from the other known forms in the flatness of the cranium, including all of its lobes.

In *Pterygomietopus intermedius* (Walcott), from the Black River formation of the upper Mississippi Valley, all of the lateral glabellar lobes are free (plate II, fig. 21 of this bulletin).

42. *Remopleurides missouriensis* sp. nov.

Plate XXI, fig. 17; plate XXII, figs. 17 A, B

In the best preserved cranium, the width of the glabella, at midlength of the palpebral lobes, is 7.2 mm., and each of the palpebral lobes is slightly over 0.2 mm. in width. The length of the glabella is 7 mm., and the neck segment adds 1 mm. in

estimating the length of the cranidium. The facial suture curves abruptly downward, 5 mm. from the neck furrow, for a distance of 1.2 mm., thus limiting the frontal lobe of the glabella laterally with nearly parallel parts of the facial suture. Here the width of the frontal lobe is slightly over 5 mm. Viewed from above, the anterior outline of the frontal lobe, as far back as the anterior margin of the palpebral lobes, appears rather evenly convex. Viewed from in front, or from the side, the anterior part of the cranidium rises abruptly for a height of 1 mm., then curves rapidly backward, attaining its maximum height of 2 mm. about on line with the anterior pair of glabellar furrows. Except along the frontal lobe, the glabella is only moderately convex, especially posteriorly. The palpebral lobes are 4.5 mm. in length, and extend as far back as the neck furrow. The posterior margin of the glabella is distinctly defined by an abrupt though very slight lowering of that part of the glabella forming the neck segment. The median tubercle on the neck segment is almost invisible.

There are three pairs of glabellar furrows. Of these the middle pair is the longest. They are 2 mm. in length, and are separated by a distance of 2 mm. Both furrows are slightly curved, with their convex sides facing forward. Their outer termination is slightly in advance of the inner one. The anterior pair of glabellar furrows are about 1 mm. long, and are separated by a distance of 2 mm. They also are slightly convex toward the front. The posterior pair of glabellar furrows are slightly over 1 mm. in length; they are separated by a distance of almost 3 mm., and they are more convexly curved than either of the other two pairs of furrows. All three pairs of furrows consist of smooth lines, scarcely 0.1 mm. in width, in their present condition appearing as slightly darker lines contrasted with the whiter adjoining parts of the cranidium.

The surface of the cranidium is marked by minute granules which become larger toward the margin of the cranidium. Under a microscope the granules are seen to be elongated transversely. Anteriorly, their upper surface slopes gradually downward. Posteriorly, the slope is more or less abrupt, often being

limited by a more or less lunate outline which becomes conspicuous on cross-illumination.

The hypostoma closely resembles that of *Remopleurides striatulus* Walcott (Cincinnati Quarterly Journal of Science, II, 1875, p. 347) in general form, and is 6 mm. in length.

From localities 2 and 4 in the Sanders Branch section, in the Kimmswick limestone.

In *Remopleurides striatulus* Walcott (plate II, figs. 18 A, B, C, of this Bulletin), from the Trenton of New York, the smooth lines indicating the glabellar furrows are indistinct, those corresponding to the anterior and posterior pairs being extremely obscure. The general curvature of the glabella is very moderate except at its anterior margin, where the frontal lobe curves more strongly downward.

Compared with *Remopleurides striatulus*, the Ralls County specimens have much more distinct indications of the glabellar furrows; the frontal lobe curves downward more strongly and for a greater distance; and the general aspect of the glabella is somewhat narrower and less flattened.

In *Remopleurides linguatus* Ruedemann, from the basal Trenton (Rysedorph) of New York, the anterior extension of the frontal lobe is much narrower and more prolonged.

In *Remopleurides tumidus* Ruedemann, from the same horizon and locality, the glabella is relatively broader, the anterior extension of the frontal lobe is shorter, and it is bounded laterally by more converging facial sutures; moreover, the convexity of the cranidium from front to rear is greater.

43. *Bathyurus spiniger* Hall

Plate XXII, fig. 20

Cranidium with posterior margin of neck ring dentate on each side of the median spine. Those parts of the cranidium which are immediately posterior to the palpebral lobes are indistinctly preserved. From the top of the Platin limestone, in the city quarry, 1 mile southeast of New London, in Ralls county.

APPENDIX: SILURIAN SPECIES

44: *Platymerella manniensis* Foerste*Plate XXIII, figs. 5 A-H*

Platymerella manniensis Foerste, originally described from the Brassfield of western Tennessee, and later found by Savage in the basal part of the Sexton Creek equivalent of the Brassfield in northeastern Missouri and adjacent Illinois, and also in the northeastern corner of Illinois, has been found recently in the basal layers of the Brassfield at Lawshe, in Adams County, Ohio. The Lawshe specimens are of special interest on account of exposing the interior of the valves. Viewed from the exterior, the dissociated valves are so closely similar that it is difficult to distinguish the pedicel valves from the brachial ones. When attached to each other, the umbo of the pedicel valve rises farther above the hinge-line, so that the beak is more curved.

Pedicel valve (figs. 5 A, B, C, D) with an oval or rhomboid spondylium, about 5 mm. long, strongly divergent from the surface of the interior of the valve, and supported by a thin, tall median septum which disappears within 5 mm. from the anterior margin of the spondylium. Pitted ovarian markings are present on the posterior part of the interior.

Brachial valve (figs. 5 E, F, G) with two short crural plates, about 3 or 4 mm. in length, converging along the median line and forming a cruralium resting directly upon the bottom of the interior of the valve. The crural prolongations of the anterior margin of the crural plates rarely are preserved. Along the median line of the shell the anterior part of the cruralium is prolonged into a low and narrow septal line. In one specimen (fig. 5 H) the crural plates rest directly upon the bottom of the interior of the valve, and are prolonged anteriorly into two sharp parallel ridges, about a millimeter in height, 3 or 4 mm. long, and slightly over 2 mm. apart.

The genus *Platymerella* is characterized by its flattened, elongate form; the absence of a cardinal area; the delthyrium is concealed entirely by the contact of the beaks of the two

valves with each other; both the spondylia and cruralia are short, the former being supported on a high median septum and the latter being sessile along the median line on bottom of the interior of the valve. The exterior of the pedicel valve shows no tendency toward a median depression or groove. The genus is regarded as related most nearly to *Pentamerella*, a Devonian genus. In *Pentamerella* the shell is short, deep, and galeatiform, the spondylium is not supported by a long septum, there is a tendency toward a narrow sinus on the exterior of the pedicel valve, the delthyrium is exposed, there is a pseudo-cardinal area, and the anterior septal extensions of the crural plates unite at the base so as to form a cruralium resting on the inner surface of the brachial valve.

PLATE XXI

Fig. 1. *Strophomena* cf. *incurvata*. Pedicel valve. Locality 3 on Sanders branch, in Kimmswick limestone.

Figs. 2, 3. *Rafinesquina deltoidea*. Pedicel valves. Locality 4 on Sanders branch, in Kimmswick limestone.

Fig. 4. *Parastrophia hemiplicata* var. Pedicel valve. Locality 4 on Sanders branch, in Kimmswick limestone.

Fig. 5. *Platystrophia shepardi*. Brachial valve. Locality 3 on Sanders branch, in Kimmswick limestone.

Fig. 6. *Holopea* cf. *parvula*. From Conn's Ford, at top of Platin limestone.

Fig. 7. *Holopea concinnula*. From Conn's Ford, at top of Platin limestone.

Fig. 8. *Hormotoma gracilis angustata*. From Conn's Ford, at top of Platin limestone.

Fig. 9. *Conularia* sp. Enrolled fragments. From city quarry, 1 mile south-east of New London, near top of Platin limestone.

Fig. 10. *Hyalithes baconi*. A, convex side of fragment, with lower end restored; from Buford cave. B, flattened side of second specimen, from J. H. Smith farm. Both from top of Platin limestone.

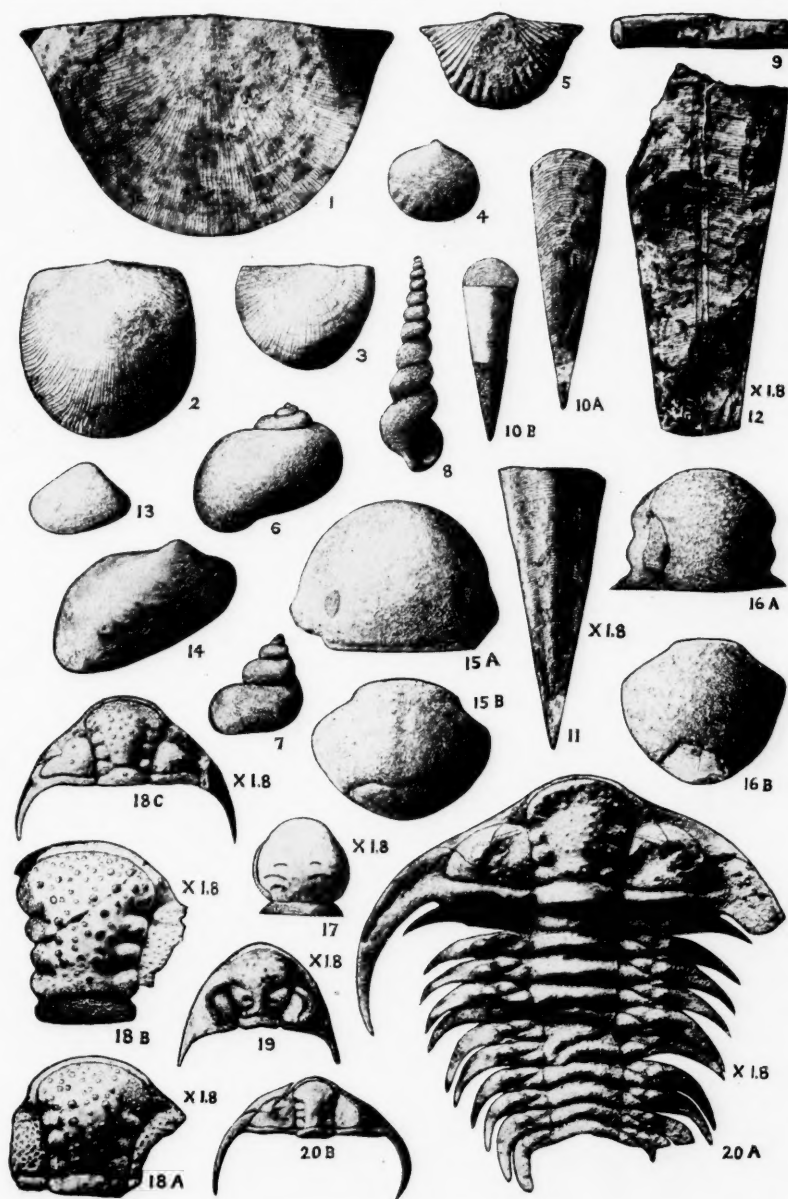
Fig. 11. *Hyalithes baconi*. Convex side. From Buford Cave, at top of Platin limestone.

Fig. 12. *Conularia plattinensis*. Fragment apparently exposing almost all of one face. From Conn's Ford, at top of Platin limestone.

Fig. 13. *Ctenodonta* sp. (*gibberula* group). Left valve. From 1 mile north-west of Spalding Springs, near home of H. W. Ogle, at top of Platin limestone.

Fig. 14. *Parallelodus obliquus*. Right valve. From Conn's Ford, at top of Platin limestone.

Fig. 15. *Bumastus holei*. A, cranidium; B, pygidium. From locality 3 on Sanders branch, in Kimmswick limestone.



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Fig. 16. *Bumastus rowleyi*. *A*, cranidium; left side restored; *B*, pygidium. Locality 3 on Sanders branch, in Kimmswick limestone.

Fig. 17. *Remopleurides missouriensis*. Cranidium, with the smooth lines representing the glabellar furrows darkened. Locality 2 on Sanders branch, in Kimmswick limestone.

Fig. 18. *Ceraurus* cf. *bispinosus*. *A*, *B*, fragments of cranidia with traces of ocular ridge on right side. *C*, cephalon lacking the free cheeks, genal spine on right side restored. Locality 2 on Sanders branch, in Kimmswick limestone.

Fig. 19. *Pterygometopus* cf. *lincolnensis*. Cephalon, left side and part of margin restored. From Buford Cave, at top of Plattin limestone.

Fig. 20. *Ceraurus plattinensis*. *A*, an almost entire individual, proximal parts of genal spines widened by crushing; from city quarry, one mile southeast of New London. *B*, Cephalon, from Harvey farm on lower Big Creek, at top of Plattin limestone.

Additional figures of some of the specimens illustrated on this plate appear on the following plate.

PLATE XXII

Fig. 1. *Strophomena incurvata*. Curvature of median line of valves of specimen figured on preceding plate; with pedicel valve on right.

Figs. 2, 3. *Rafinesquina deltoidea*. Outlines of specimens figured on preceding plate, viewed from the side.

Fig. 4. *Parastrophia hemiplicata* var. *A*, second specimen, from same locality as that figured on preceding plate, weathered so as to show spondylium formed by dental lamellae, supported by median septum anteriorly.

Fig. 5. *Zygospira deflecta*. *A*, pedicel valve; *B*, anterior view; from the Trenton of Lewis County, New York. Copied from figures 4 *a*, *b*, on plate 33, of Pal. New York, 1, 1847.

Fig. 6. *Holopea parvula*. From Flanagan member, near top of Trenton, near Burgin, in central Kentucky. Copied from figure 19, on plate 79, of Pal. Minnesota, III, pt. 2, 1897.

Fig. 7. *Holopea concinnula*. From the Platteville near Beloit, Wisconsin. Copied from figure 6 on plate 79 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 8. *Hormotoma gracilis angustata*. From top of Decorah formation at Cannon Falls, Minnesota. Copied from figure 32 on plate 70 of Pal. Minnesota III, pt. 2, 1897.

Fig. 9. *Conularia* sp. *A*, granular surface, magnified 12 diameters, to show arrangement of granules in transverse and in longitudinal rows. *B*, several cross-sections of the enrolled fragments. From same series as the specimen represented by figure 9 on the preceding plate.

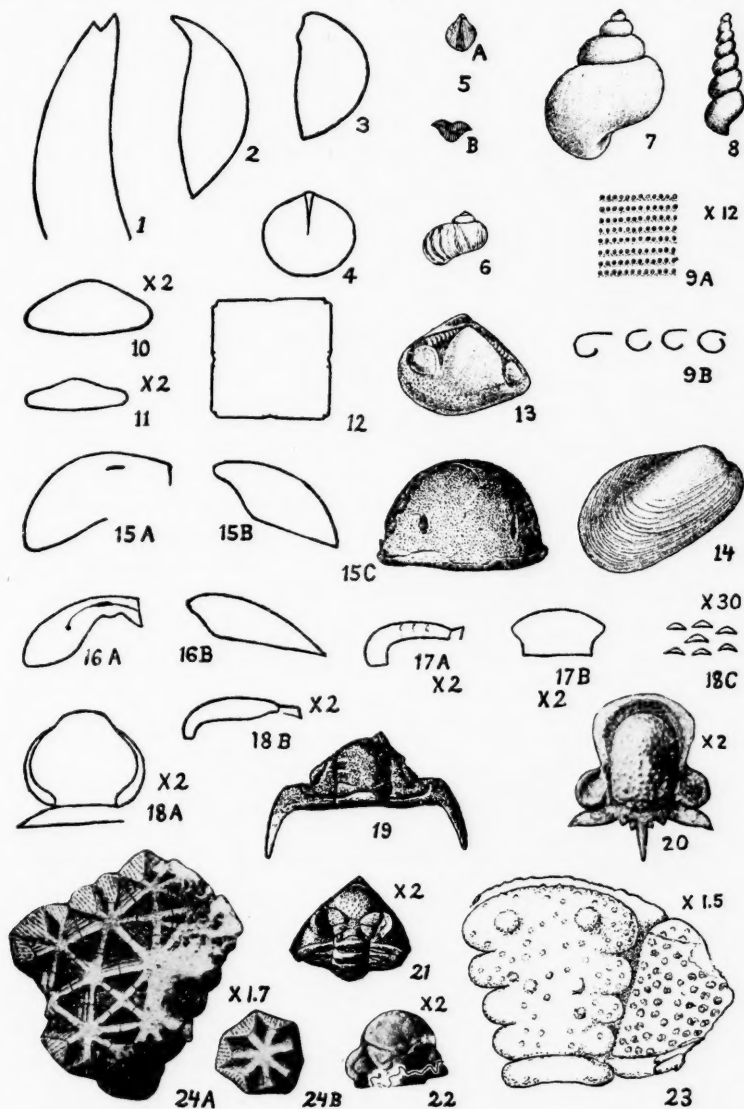
Fig. 10. *Hyalithes baconi*. Cross-section of specimen used for figure 10 *B*, on preceding plate.

Fig. 11. *Hyalithes baconi*. Cross-section of specimen used for figure 11 on preceding plate.

Fig. 12. *Conularia plattinensis*. Imaginary cross-section of specimen similar to that used for figure 12 on preceding plate, indicating position of the pair of vertical ridges along the median part of the faces, supported interiorly by short septal striations.

Fig. 13. *Ctenodonta gibberula*. Mould of interior of left valve, from the Platteville at Minneapolis, Minnesota. Copied from figure 37 on plate 42 of Pal. of Minnesota, III, pt. 2, 1897.

Fig. 14. *Modiolopsis consimilis*. Right valve, from the Stones river group at Murfreesboro, Tennessee. Copied from figure 17 on plate 42 of Pal. Minnesota, III, pt. 2, 1897.



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Fig. 15. *Bumastus cf. billingsi*. *A, B*, outlines of cranium and pygidium figured on preceding plate, viewed from the side. *C*, specimen figured by Clarke as *Bumastus orbicaudatus*; copied from figure 36 on page 722, of Pal. Minnesota, III, pt. 2, 1897.

Fig. 16. *Bumastus rowleyi*. *A, B*, outlines of cranium and pygidium figured on preceding plate, viewed from the side.

Fig. 17. *Remopleurides missouriensis*. *A*, outline of specimen figured on preceding plate, viewed from the side; *B*, viewed from the front, showing the frontal lobe.

Fig. 18. *Remopleurides striatulus*. *A*, specimen from type locality, in U. S. Nat. Mus., viewed from above; *B*, lateral view of same; *C*, short nodose striations, magnified 50 diameters. From Trenton limestone at Trenton Falls, New York.

Fig. 19. *Ceraurus sciofieldi*. Cranium, from Platteville limestone at Minneapolis, Minnesota. Copied from figure 55 on page 735 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 20. *Bathyrus spiniger*. A cranium, with fixed cheeks posterior to palpebral lobes indistinctly defined. From city quarry, 1 mile southeast of New London, near top of Platin limestone.

Fig. 21. *Pterygomotopus intermedius*. Cephalic view of enrolled specimen; species occurs both in Platteville and Decorah of Minnesota. Copied from figure 45 on page 728 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 22. *Pterygomotopus confluens*. Cranium from Tyrone member of strata exposed at High Bridge, Kentucky. Showing confluence of outer parts of first and second pairs of glabellar lobes, as in *Pterygomotopus eboraceus* and *Pt. tircolnensis*.

Fig. 23. *Ceraurus hispidus*. Fragment of cranium, from Black River limestone at Tetreauville, province of Quebec. Copied from figure 4 on plate I of Bulletin of Museum of Comparative Zoology, 54, no. 20, 1913.

Fig. 24. *Comarocystites shumardi*. *A*, fragment of theca adjoining anal aperture, viewed from interior. *B*; a single thecal plate viewed from interior. From top of quarry in Kimmswick limestone, $\frac{1}{2}$ mile northwest of West Kimmswick, Missouri.

PLATE XXIII

Fig. 1. *Mcewanella raymondi*. Brachial valve. From Mineke, St. Louis County, Missouri; in Kimmswick limestone.

Fig. 2. *Rhynchotrema rowleyi*. *A, B*, pedicel valves, exteriors. *C*, pedicel valve, interior. *D*, brachial valve, interior. From small knob, 3 miles east of Frankford, on road to Louisiana; in Buffalo or Maquoketa shales.

Fig. 3. *Ceraurus plattinensis*. *A*, pygidium. *B*, hypostoma. From Buford Cave, 2 miles west of New London; at top of Platin limestone.

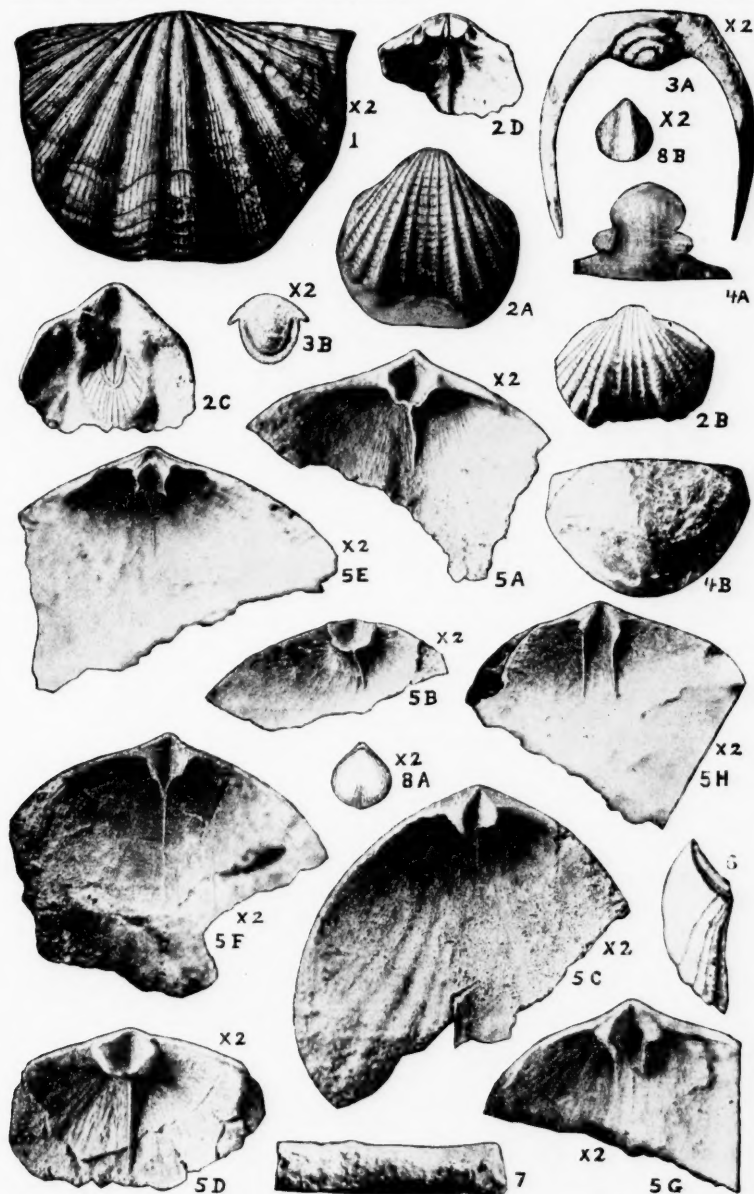
Fig. 4. *Nileus* sp. *A*, cranium. *B*, pygidium. From a coarse limestone layer immediately beneath the Buffalo or Maquoketa shales, east of the home of W. H. Benham, 3 miles south of Frankford, on a branch of Peno creek.

Fig. 5. *Platymarella manniensis*. *A-D*, pedicel valves, interiors. *E-H*, brachial valves. From Lawshe, Adams County, Ohio. In basal part of Brassfield formation.

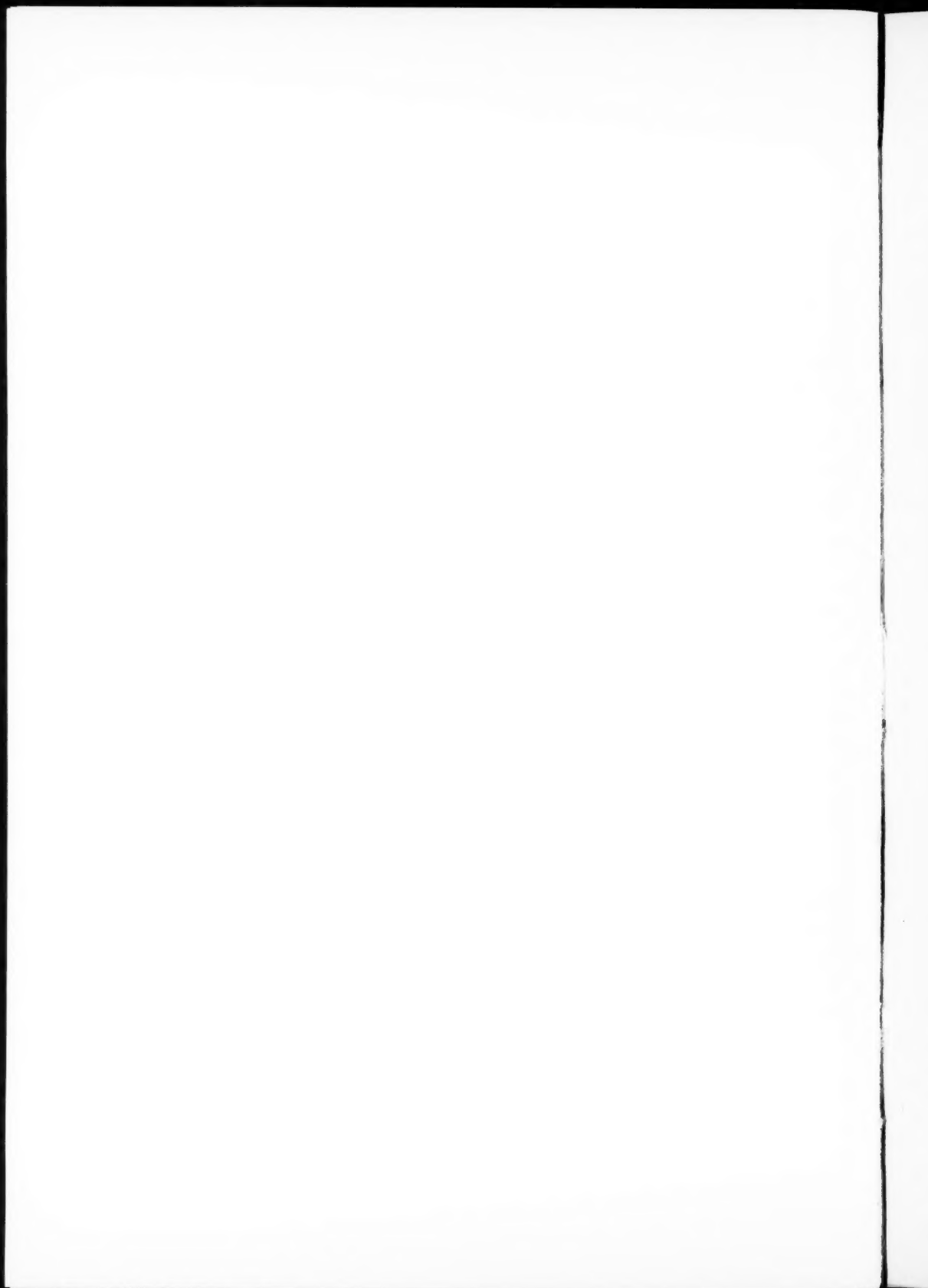
Fig. 6. *Clitambonites cf. diversus*. Pedicel valve, lateral view. From Mineke, in St. Louis County, Missouri; in Kimmswick limestone.

Fig. 7. *Beatricea gracilis* Ulrich. Lateral view of fragment of a much longer stem. From quarry east of pike, a short distance north of Auburn, Missouri; in Auburn limestone.

Fig. 8. *Zygospira nicolleti*. *A*, brachial valve. *B*, pedicel valve. From Buford Cave, 2 miles west of New London, at top of Platin limestone.



FOERSTE: BRASSFIELD, MAQUOKETA, KIMMSWICK AND PLATTIN FOSSILS



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